Cambridge Assessment International Education

AS Level
Chapter 8

Transport in Mammals

Chapter Outline

Part 1: The Circulatory System

- Blood Vessels: Arteries, Veins and Capillaries
- Blood Plasma vs Tissue Fluid
- WBCs and RBCs

Part 2: Transport of oxygen and carbon dioxide

- The Haemoglobin Dissociation Curve
- Bohr effect and Transport of CO_2

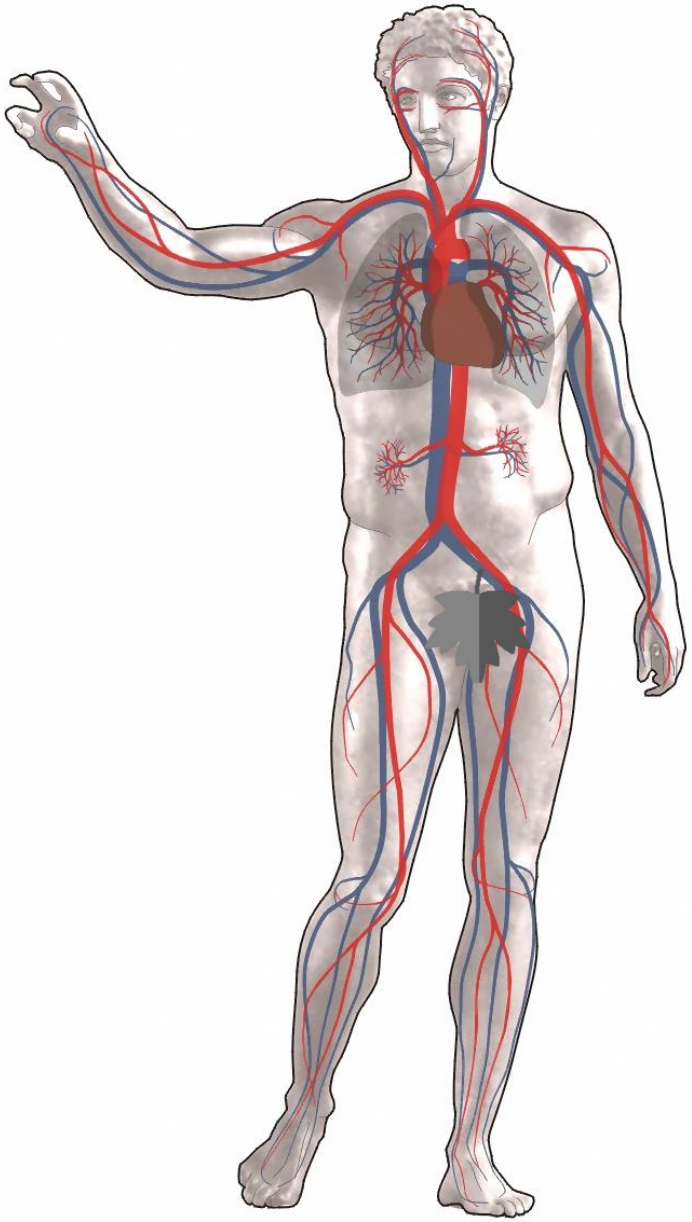
Part 3: The Heart

- Structure of the Heart
- Cardiac Cycle
- Control of Heart Beat

The Circulatory System

The Cardiovascular System

- Aka circulatory system
- Includes **blood vessels, blood, lymph and heart**



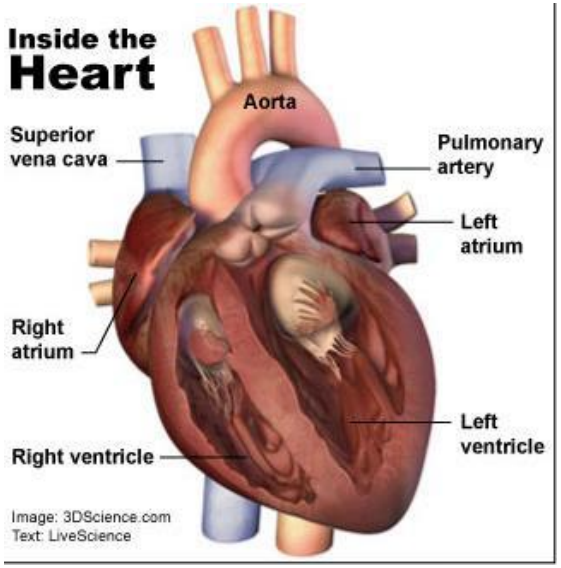
Needed for:

1. Transport of nutrients and oxygen around the body
2. Disposal of waste materials (e.g. carbon dioxide, urea)
3. Transport of hormones
4. Circulate WBCs and RBCs in body

Closed, Double Circulatory System

Closed

- **Blood is contained in blood vessels**
- Always in heart, arteries, veins or capillaries



Double

- Blood **passes through the heart twice**, in one complete circuit

Closed, Double Circulatory System

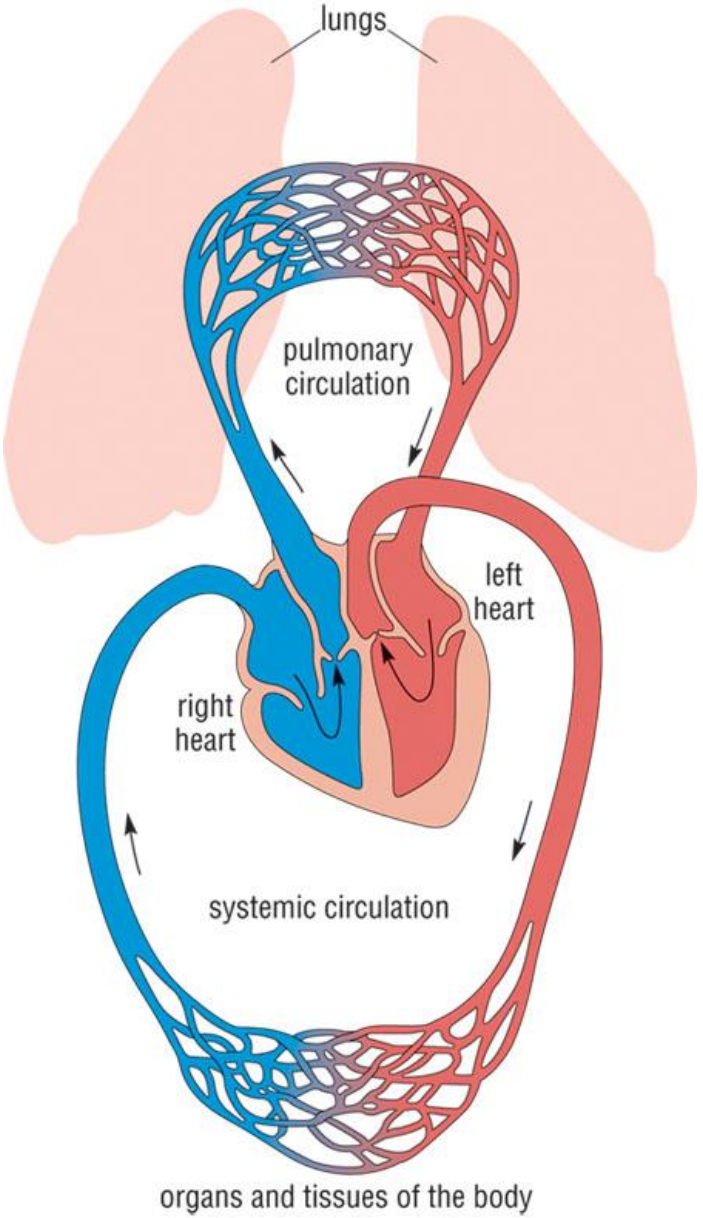
1 circuit = 2 circulations

1) **Pulmonary circulation**

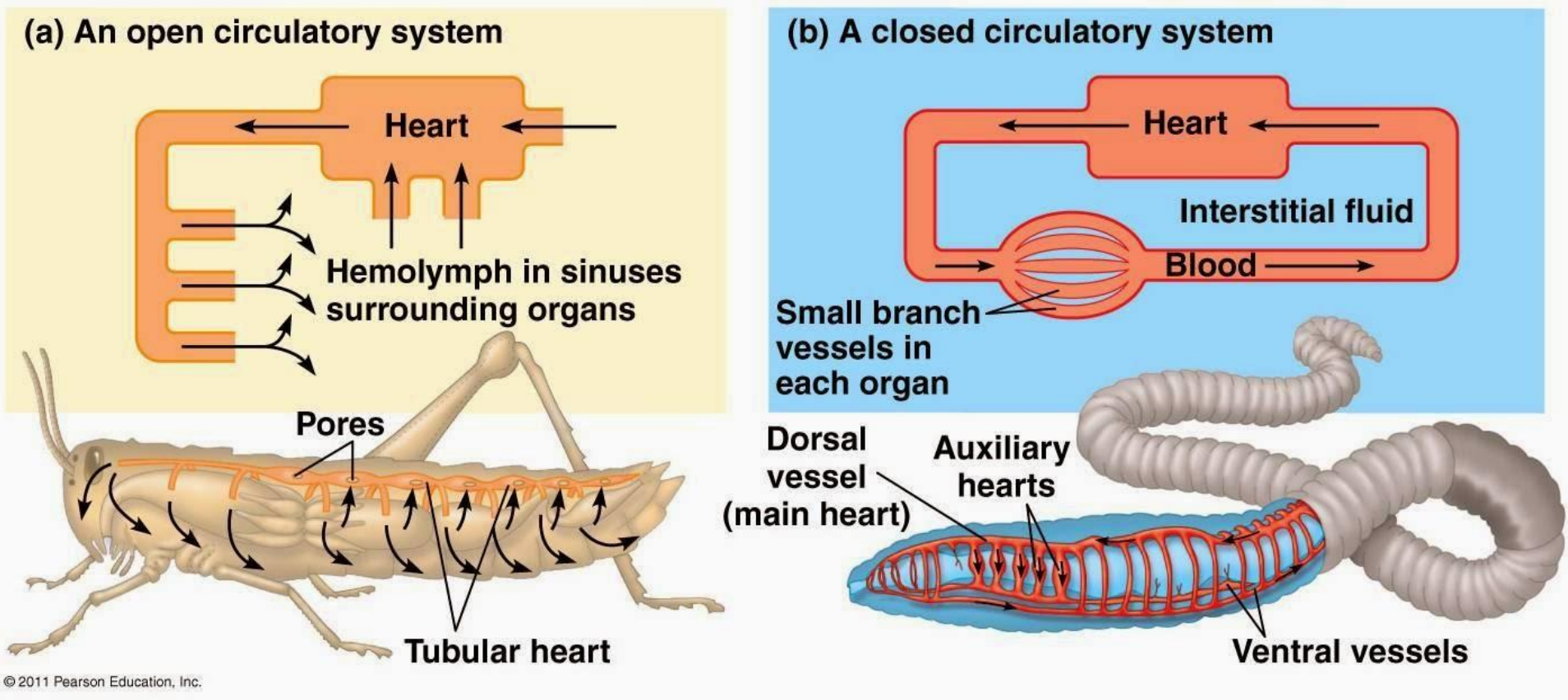
- Circulation through the lungs and heart

2) **Systemic circulation**

- Circulation through other parts of the body and heart except the lungs



Other Circulatory Systems



*don't need to remember the details

Blood Vessels

Arteries

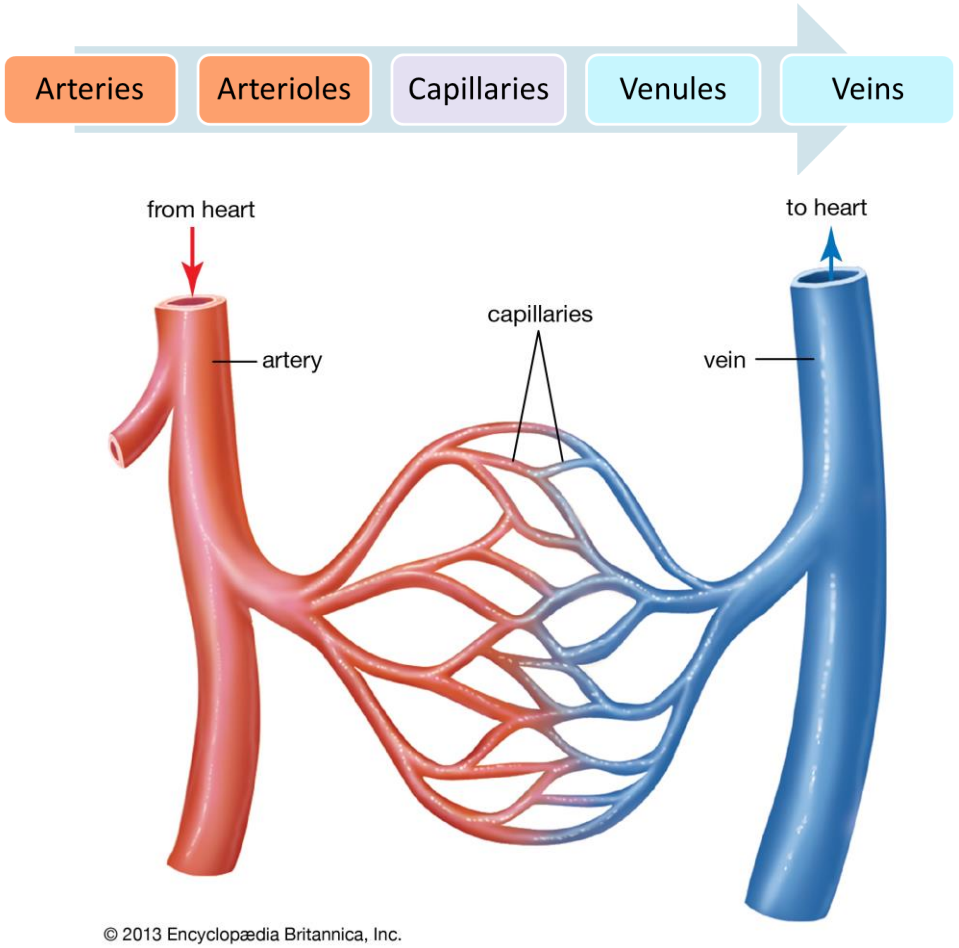
- Carry blood away from heart
- Carries oxygenated blood (except for pulmonary artery)

Capillaries

- Exchange vessels, bring blood close to tissues
- Link arteries and veins

Veins

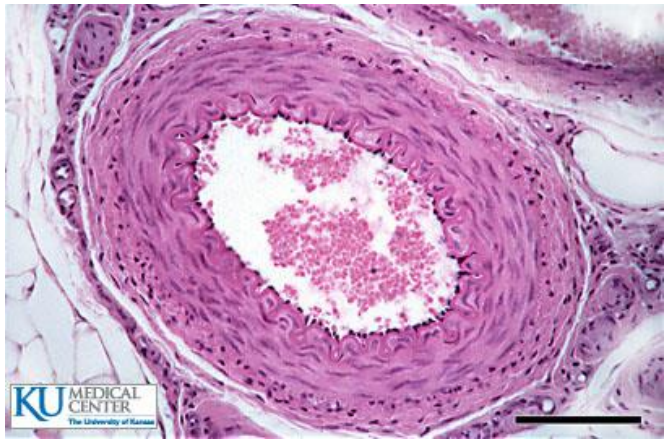
- Carry blood towards the heart
- Carries deoxygenated blood (except for pulmonary vein)



Arteries

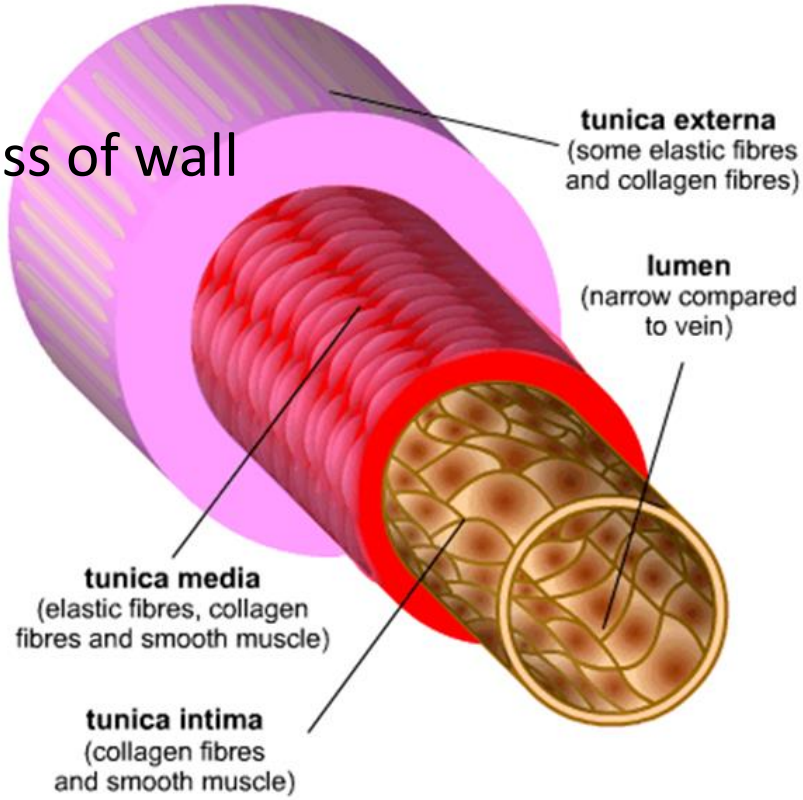
- Shorter distance from heart

→ Blood travels at **high pressure** in arteries



Appearance:

- Well-defined oval shape
- **Thick wall**
- **Narrow lumen** in relation to thickness of wall
- Folded endothelium



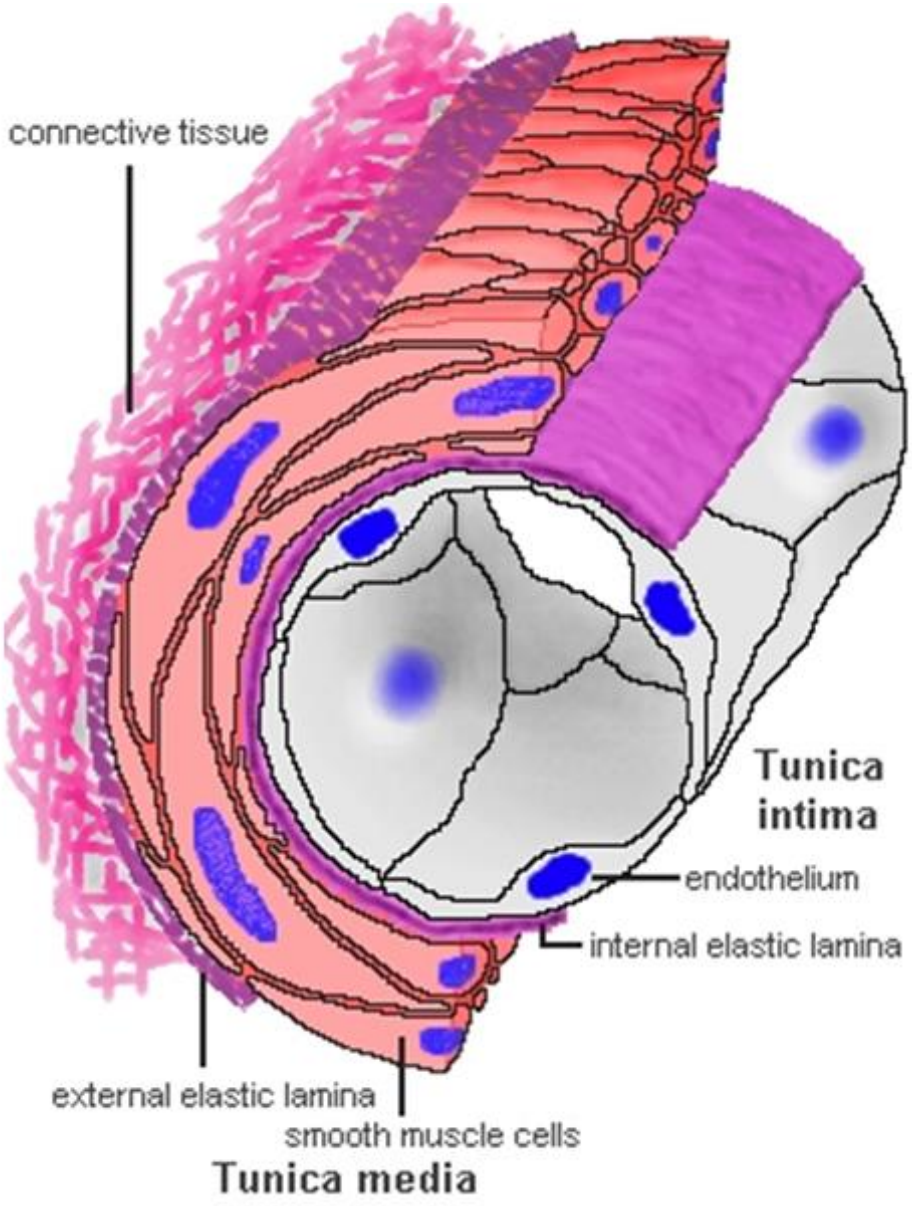
Arterial wall has 3 layers:

1. **Tunica intima / endothelium**
2. **Tunica media**
3. **Tunica externa**

Arteries

1. Tunica intima / endothelium

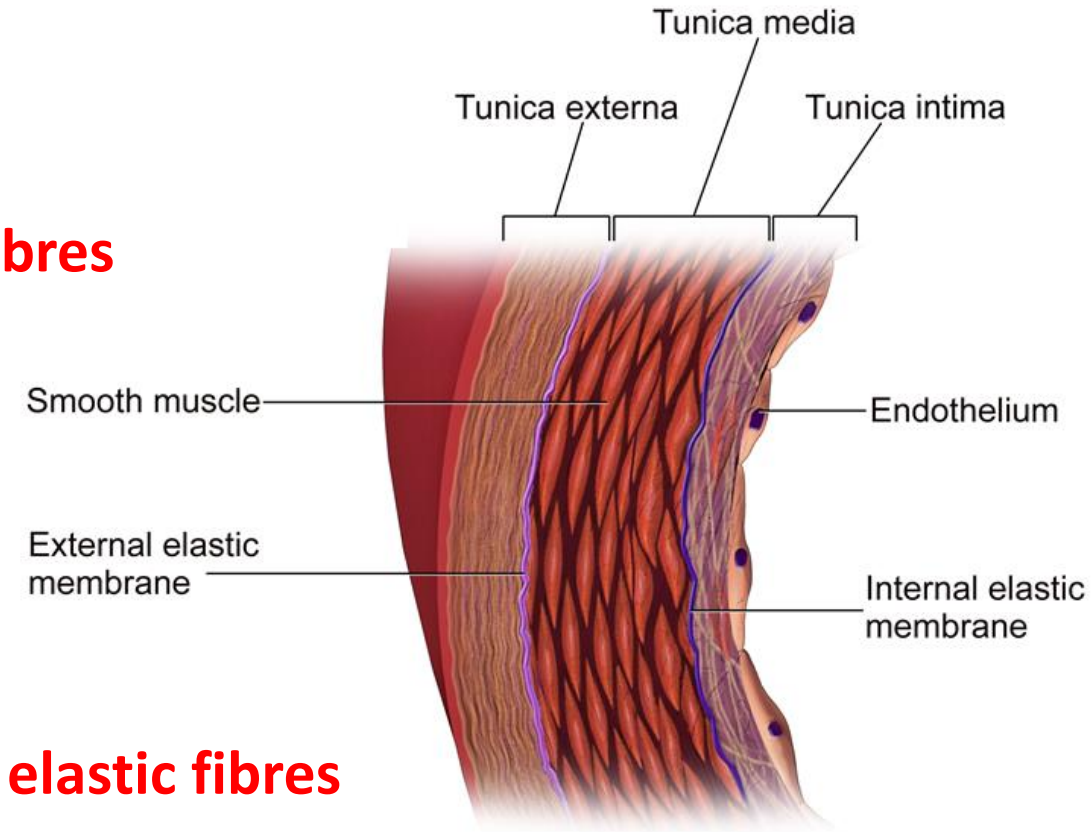
- **Squamous epithelial cells**
  = flattened cells
- One-cell thick
- Smooth surface facing lumen



Arteries

2. Tunica media

- ***THICCCEST***
- 3 components:
  Collagen fibres, elastic fibres
  and **smooth muscle**

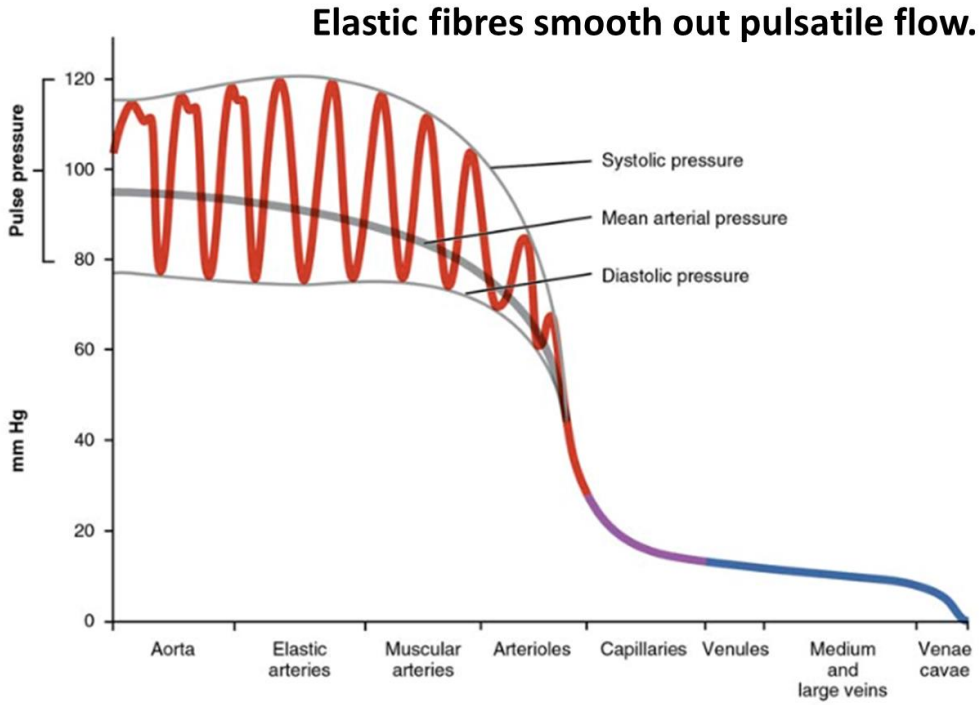


3. Tunica externa

- 2 components:
  Only **collagen fibres and elastic fibres**

Arteries

Roles of each component:



1) Collagen fibres

- **Withstand high pressure**
- Prevents rupture of vessels

2) Elastic fibres

- Allows vessel to ***stretch*** to **withstand high pressure**
- When blood enters at lower pressure, it ***recoils*** **to give blood a small push to increase blood pressure**

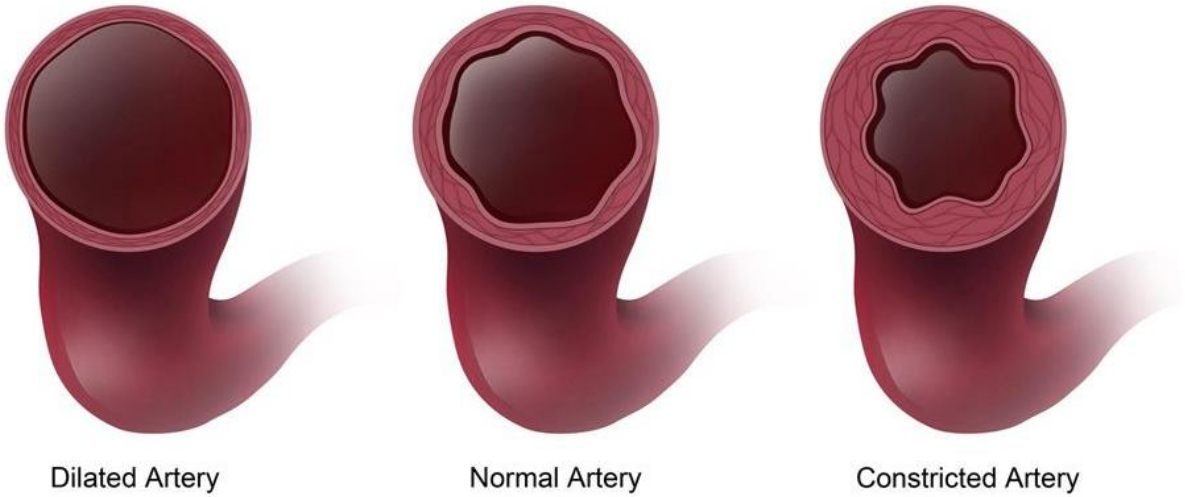
→ **Smooths out pulsatile flow**

→ **Maintains blood pressure**

Arteries

3) Smooth muscle – many layers

- Maintains blood pressure
- ***Contract / relax*** **to change volume of blood delivered**
- Keep blood moving forwards



- When muscles relax:

→ Arterioles become wide (***vasodilation***)

→ Increase blood flow

- When muscles contract:

→ Arterioles become narrow (***vasoconstriction***)

→ Reduce blood flow

Arteries → Arterioles

Arteries further from heart have **less elastic fibres** and **more smooth muscles**

1. Elastic arteries

- Closer to the heart
- Elastic fibres can stretch / recoil to **withstand high pressure** and **smooth out pulsatile flow**

2. Muscular arteries/arterioles

- Further from the heart
- Smooth muscles can contract / relax to **control volume of blood flow**
- Become narrower so **blood flow slows down**

→ More time for exchange of gases and nutrient with tissues

Capillaries

Vessel diameter = **~7µm**

Made of **endothelial / squamous epithelial cells**

Adapted for function

1) **One-cell thick**

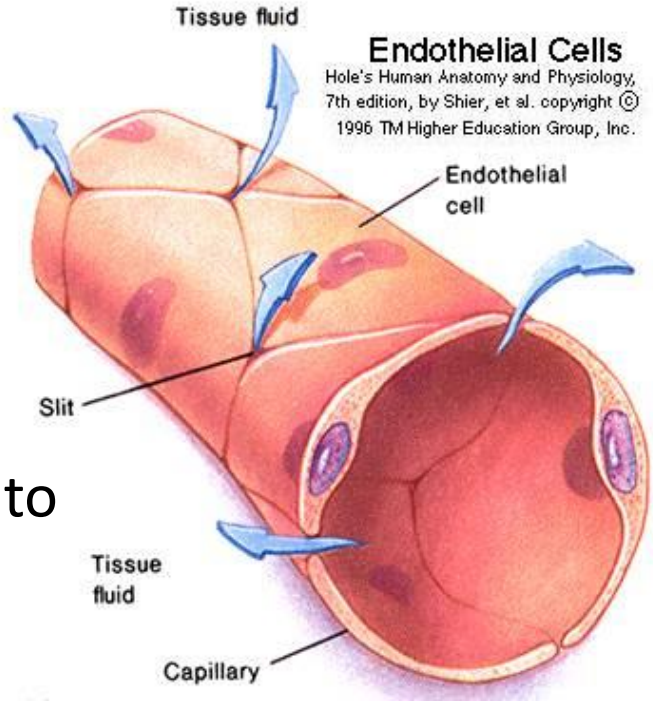
→ Short diffusion distance

2) **Has pores/gaps** between endothelial cells

→ Allow some smaller components of blood to pass through

→ E.g. water, ions, glucose

→ Allow formation of tissue fluid


Tissue fluid
Endothelial Cells
Hole's Human Anatomy and Physiology, 7th edition, by Shier, et al. copyright © 1996 TM Higher Education Group, Inc.
Endothelial cell
Slit
Tissue fluid
Capillary

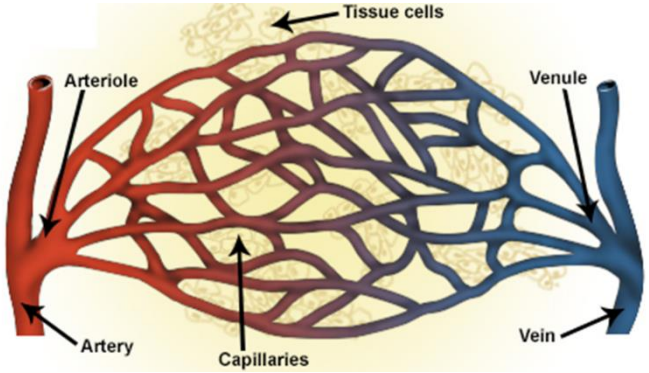
Capillaries

3) **Small lumen diameter**

→ Slows down flow of blood

→ Bring RBC close to body tissue

→ Blood pressure in capillaries are lower



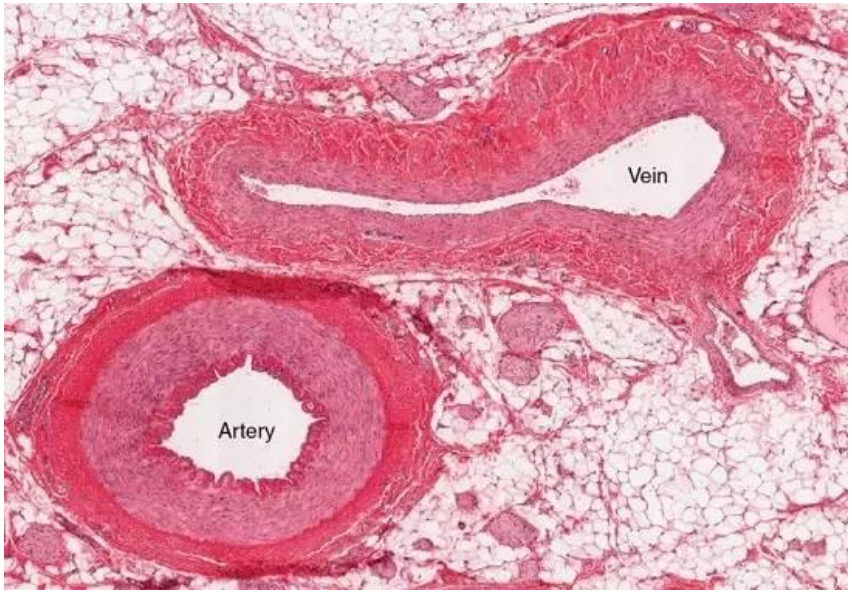
4) **Have high surface area**

→ Network of capillaries form a capillary bed

→ Allows more exchange

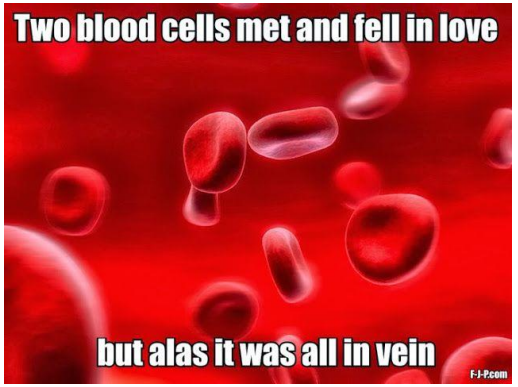
Veins

- Return blood to the heart
- **Low blood pressure**
- Slower blood flow than in artery
- Also has 3 layers



Appearance:

- Irregular/ flattened oval shape
- **Wide lumen** in relation to thickness of wall
- **Thin tunica media**
  → less elastic tissue and less smooth muscle
- Tunica intima / endothelium not wavy



Veins

Features:

1. Presence of **valves**

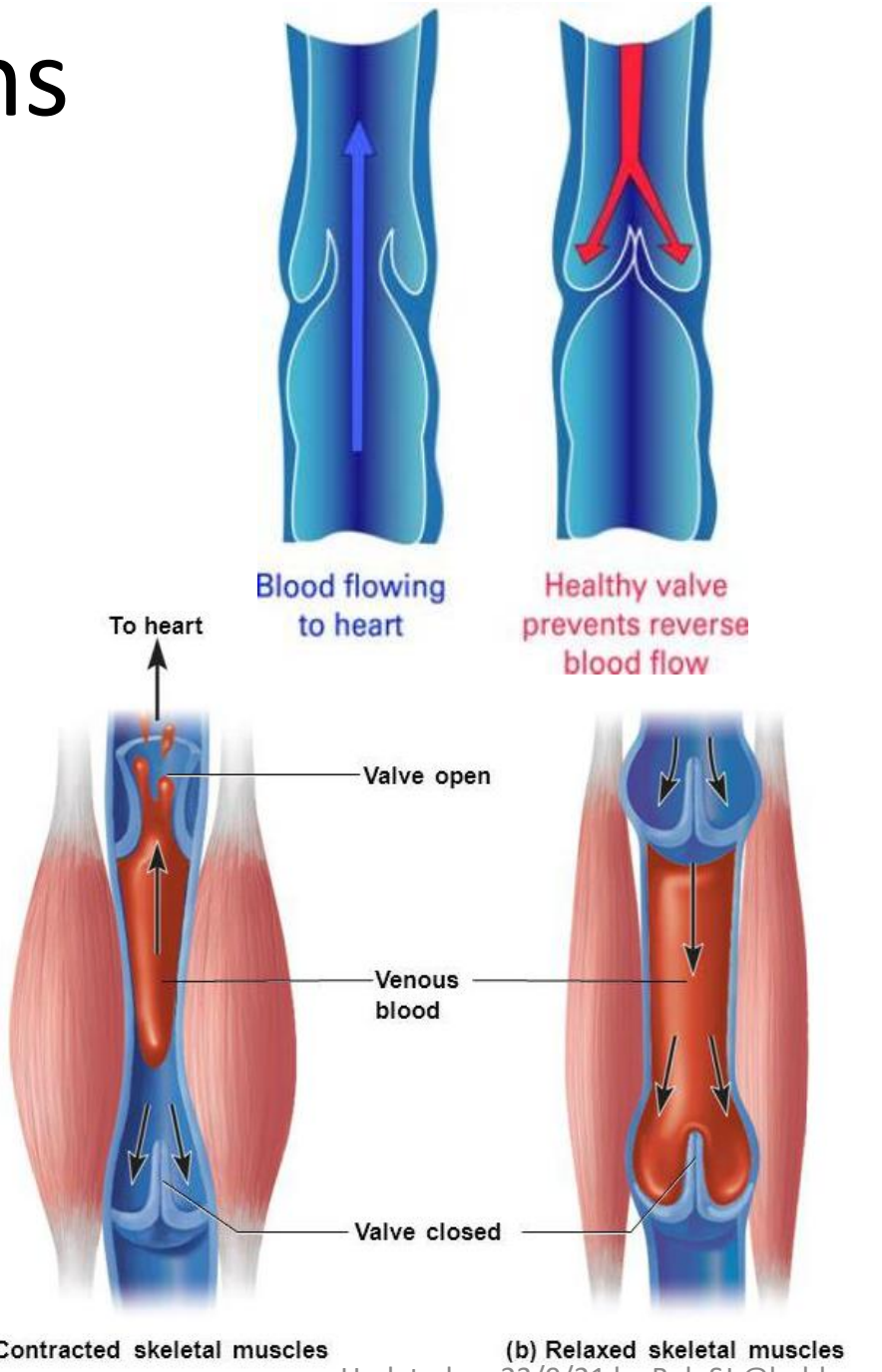
→ **To prevent backflow of blood**

→ Ensure blood flows towards heart

→ Valves close the pathway when blood travels opposite direction

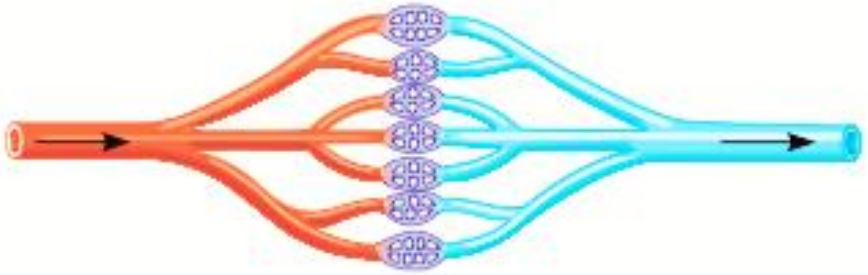
2. Surrounded by **skeletal muscles**

→ When skeletal muscle contracts, pushes blood towards heart



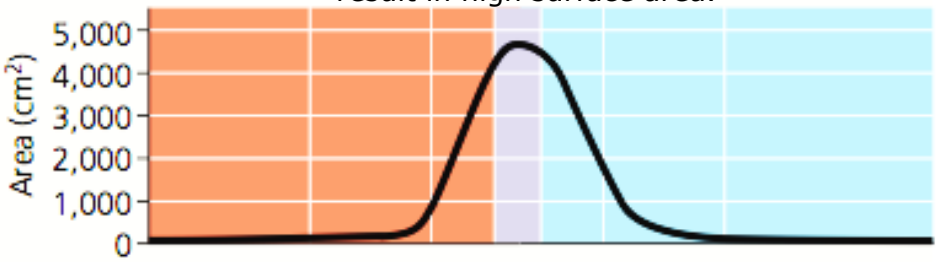
Updated on 23/9/21 by Beh SJ @behlogy

Blood Vessels

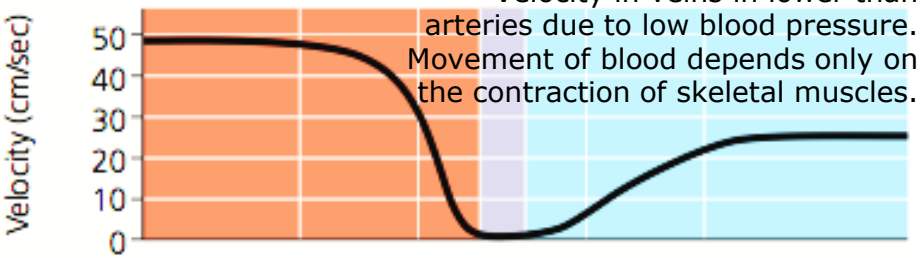


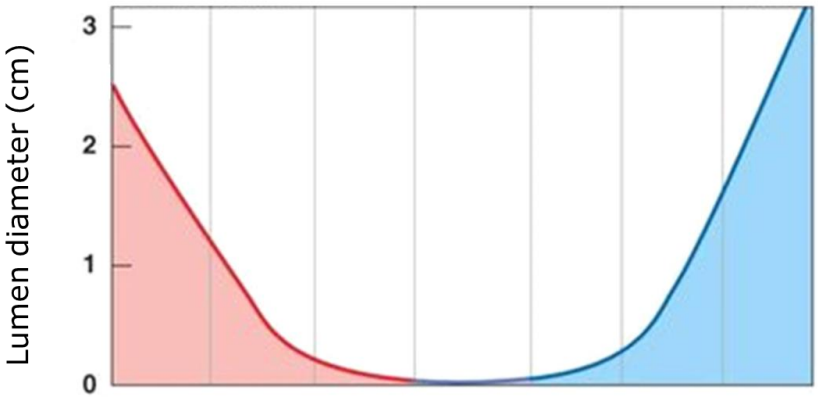
Arteries → Arterioles → Capillaries → Venules → Veins

Networks of capillaries result in high surface area.

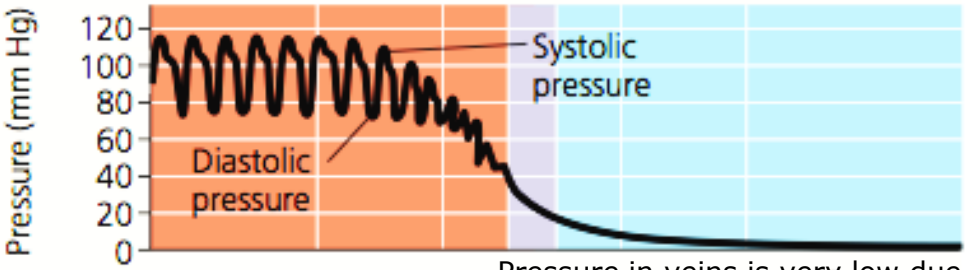


Velocity in veins in lower than arteries due to low blood pressure. Movement of blood depends only on the contraction of skeletal muscles.





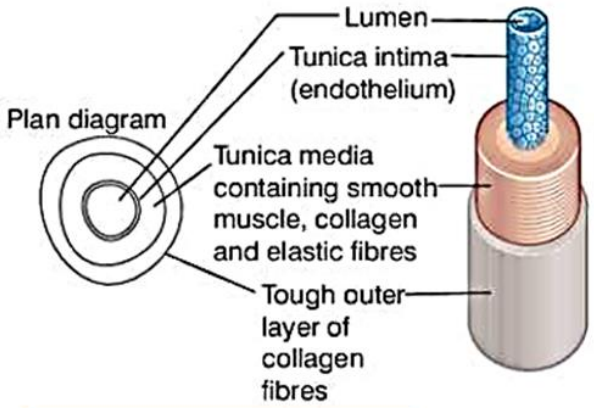
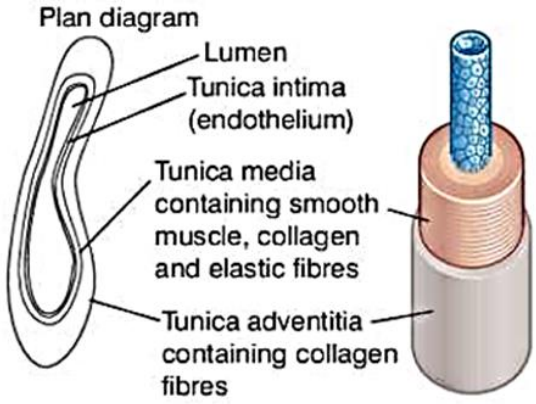
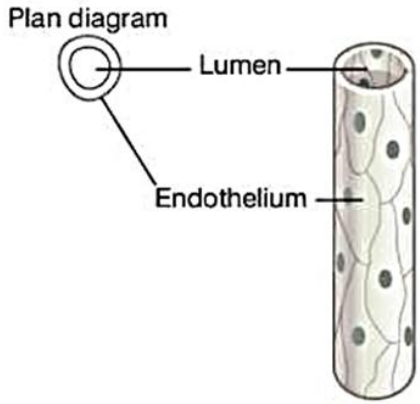
Blood pressure pulsates in the arteries due to the pumping of the heart. Elastic fibres help smooth out pulsatile flow.



Pressure in veins is very low due to distance from heart pump.

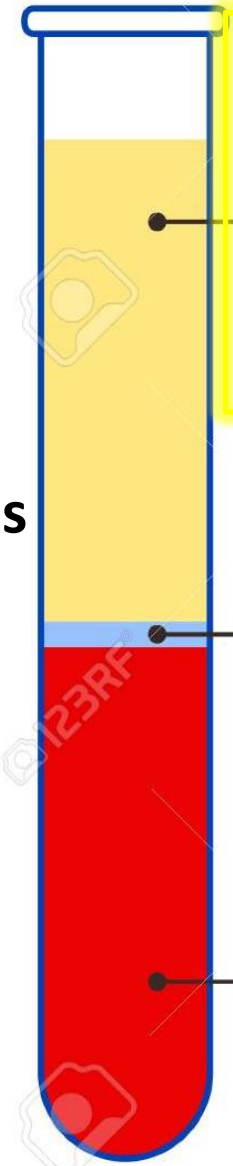
Updated on 23/9/21 by Beh SJ @behlogy

Summary

Artery	Vein	Capillary
		
Thick muscular wall Much elastic tissue Small **lumen** relative to diameter Capable of constriction Valves in aorta and pulmonary artery only Transports blood from the heart Oxygenated blood except in pulmonary artery	Thin muscular wall Little elastic tissue Large lumen relative to diameter Not capable of constriction Valves throughout all veins Transports blood to heart Deoxygenated blood except in pulmonary vein	No muscle No elastic tissue Very small lumen Not capable of constriction No valves Links arteries to veins Blood changes from oxygenated to deoxygenated Has gaps between endothelial cells Large surface area

Blood Plasma vs Tissue Fluid

Blood that is centrifuged

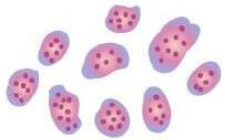


55% **Plasma**

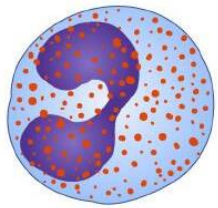
- **Water** (good solvent, high specific heat capacity)
- **Ions**
- **Proteins**
- **Nutrients** (e.g. glucose, amino acids, lipid)
- **Wastes** (e.g. urea)
- **Gases** (e.g. CO_2, O_2)

1%

- **Platelets**



- **White blood cells**

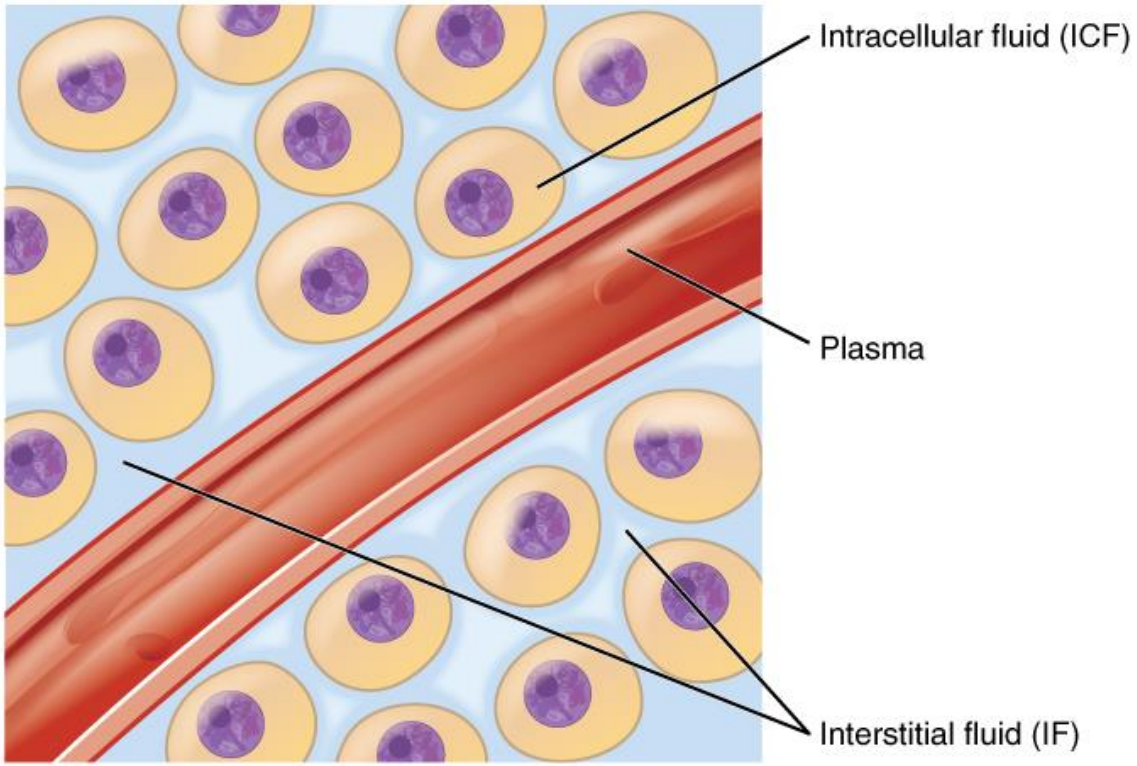


44% **Red blood cells**

Tissue Fluid

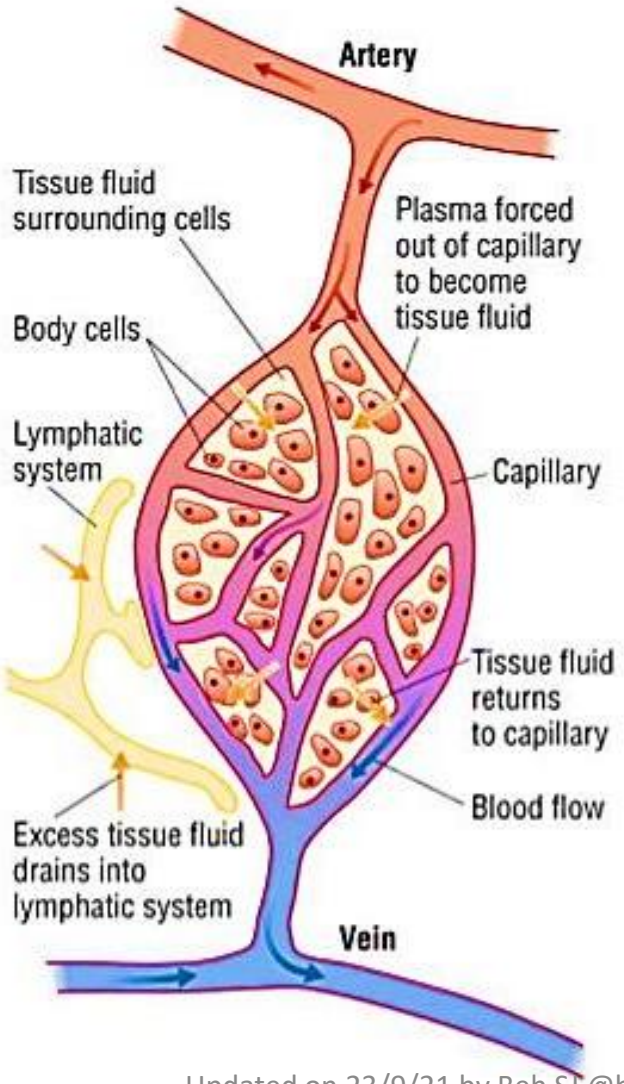
- Aka interstitial fluid
- Bathes cells
- Medium for exchange of materials between cells and blood

- **Formed from blood plasma**
- Returned to blood eventually



Formation of Tissue Fluid from Blood Plasma

- Due to differences in blood pressure at arterial and venous ends
- **Blood pressure in arterioles is higher** than blood pressure in venules



- **Blood plasma flow out** into tissue spaces

→ Through endothelial **pores** of capillaries

→ **Form tissue fluid**

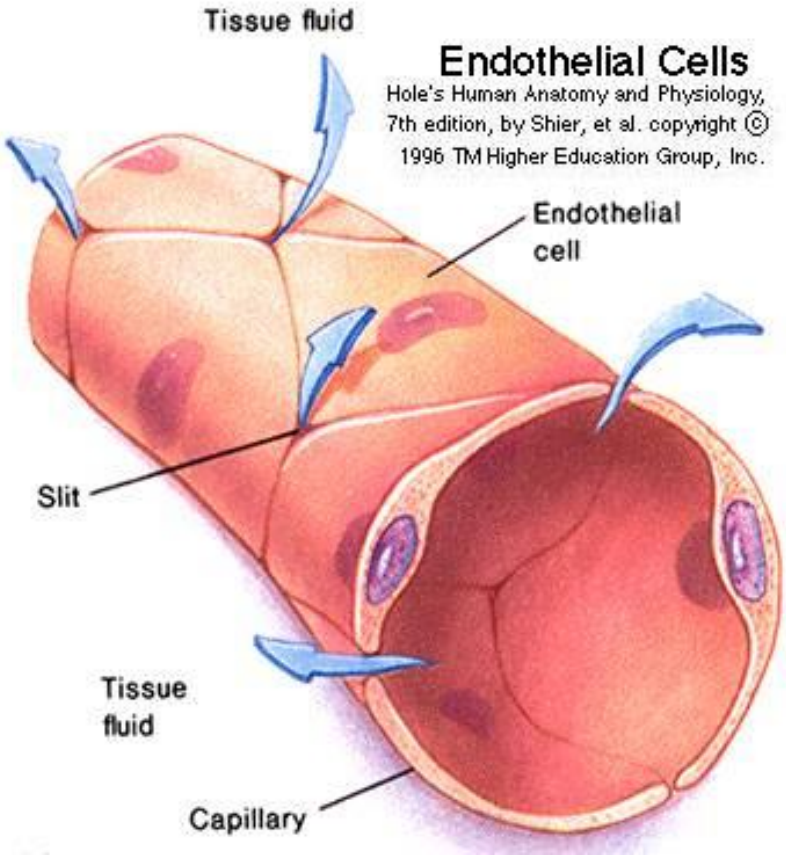
P/S: If pressure is too high, tissue fluid may accumulate in tissues and cause oedema! Arterioles have smooth muscles to reduce blood pressure to avoid this

Formation of Tissue Fluid from Blood Plasma

- But **gaps are small** so filtration occurs

→ Larger plasma proteins cannot pass through

→ RBCs cannot pass through


Tissue fluid
Endothelial Cells
Hole's Human Anatomy and Physiology, 7th edition, by Shier, et al. copyright © 1996 TM Higher Education Group, Inc.
Endothelial cell
Slit
Tissue fluid
Capillary

Composition of Tissue Fluid

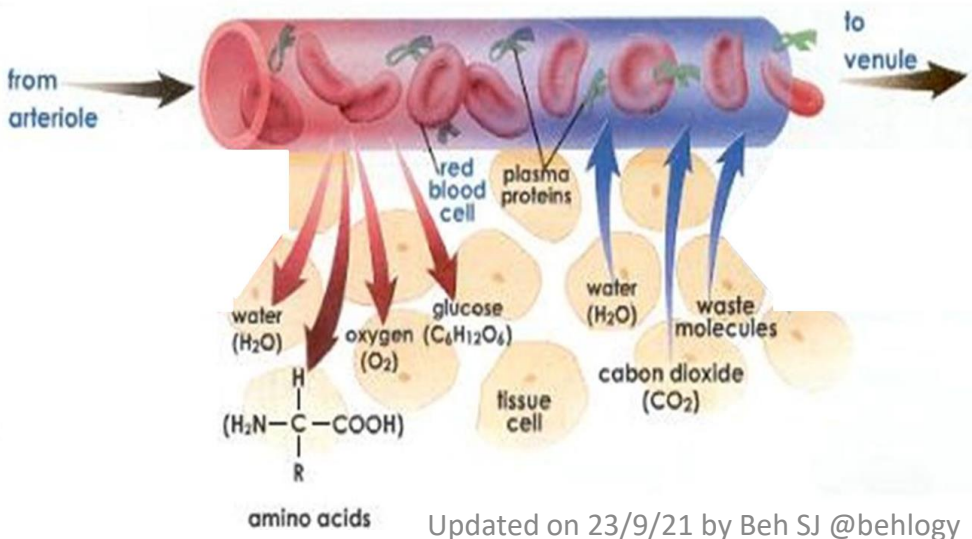
- Similar to blood plasma's composition

Tissue fluid contains:

- Water, gases, glucose, fatty acids, urea, ions
- Smaller proteins (e.g. antibodies)

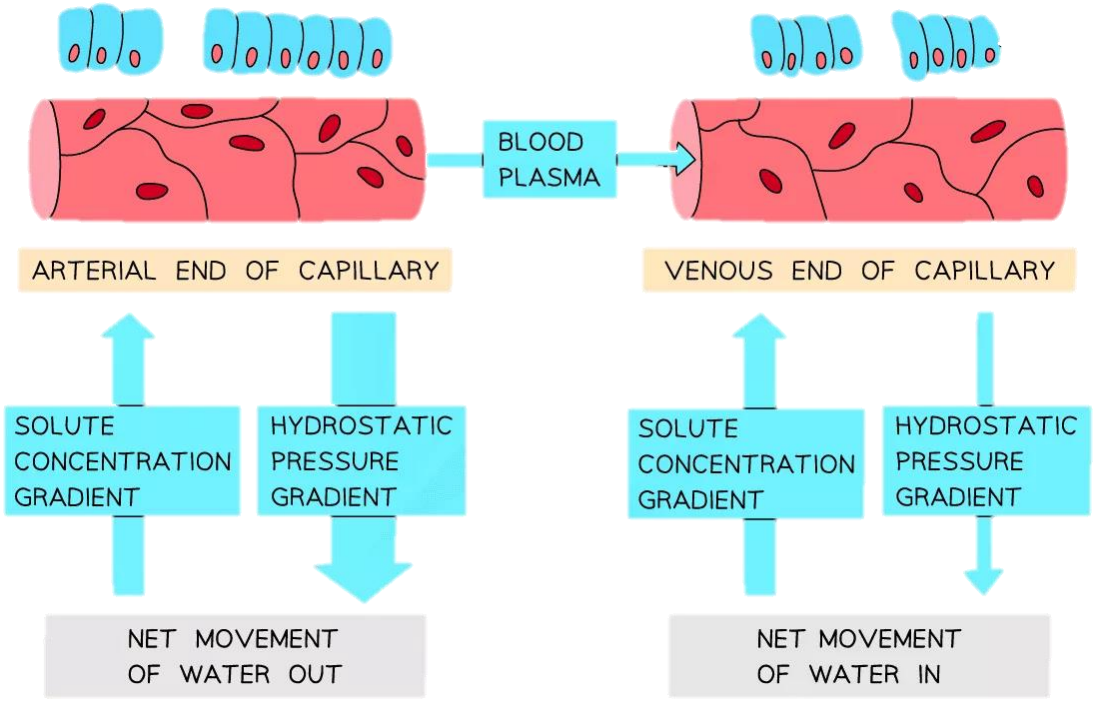
→ Overall lower protein conc. than plasma

- Some WBCs (e.g. phagocytes can leave eventho large)
- Lower O_2 conc. than plasma
- **NO platelets**
- **NO large proteins**
- **NO RBC**



Return of Tissue Fluid to Blood

- **Blood pressure** at venous end is **lower** than at arterial end
- **Solute concentration is higher** in the blood plasma of capillary due to large, dissolved proteins
- So at venous end, some tissue fluid returns to the blood

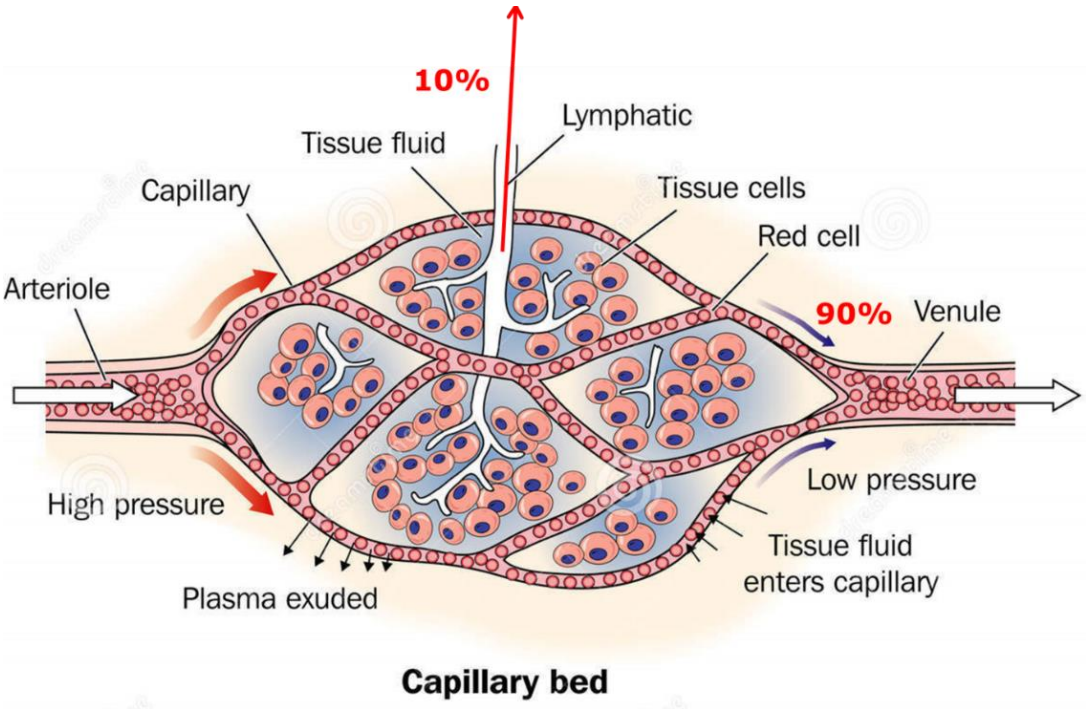


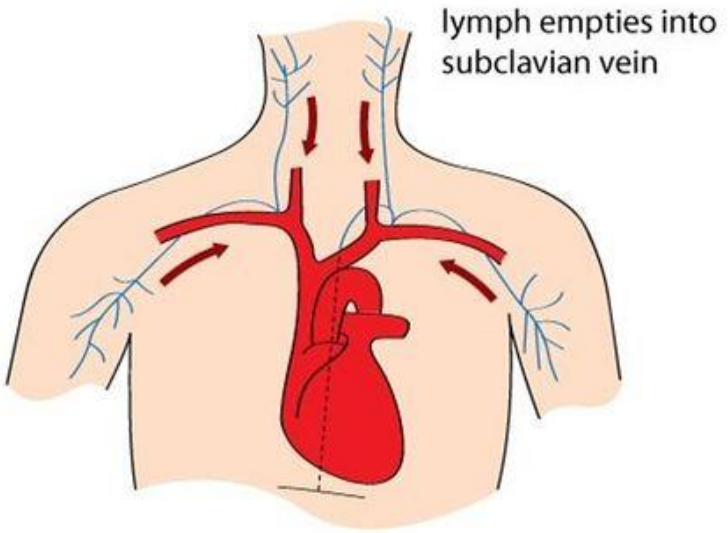
Return of Tissue Fluid to Blood

90% is returned to blood, through endothelial gaps

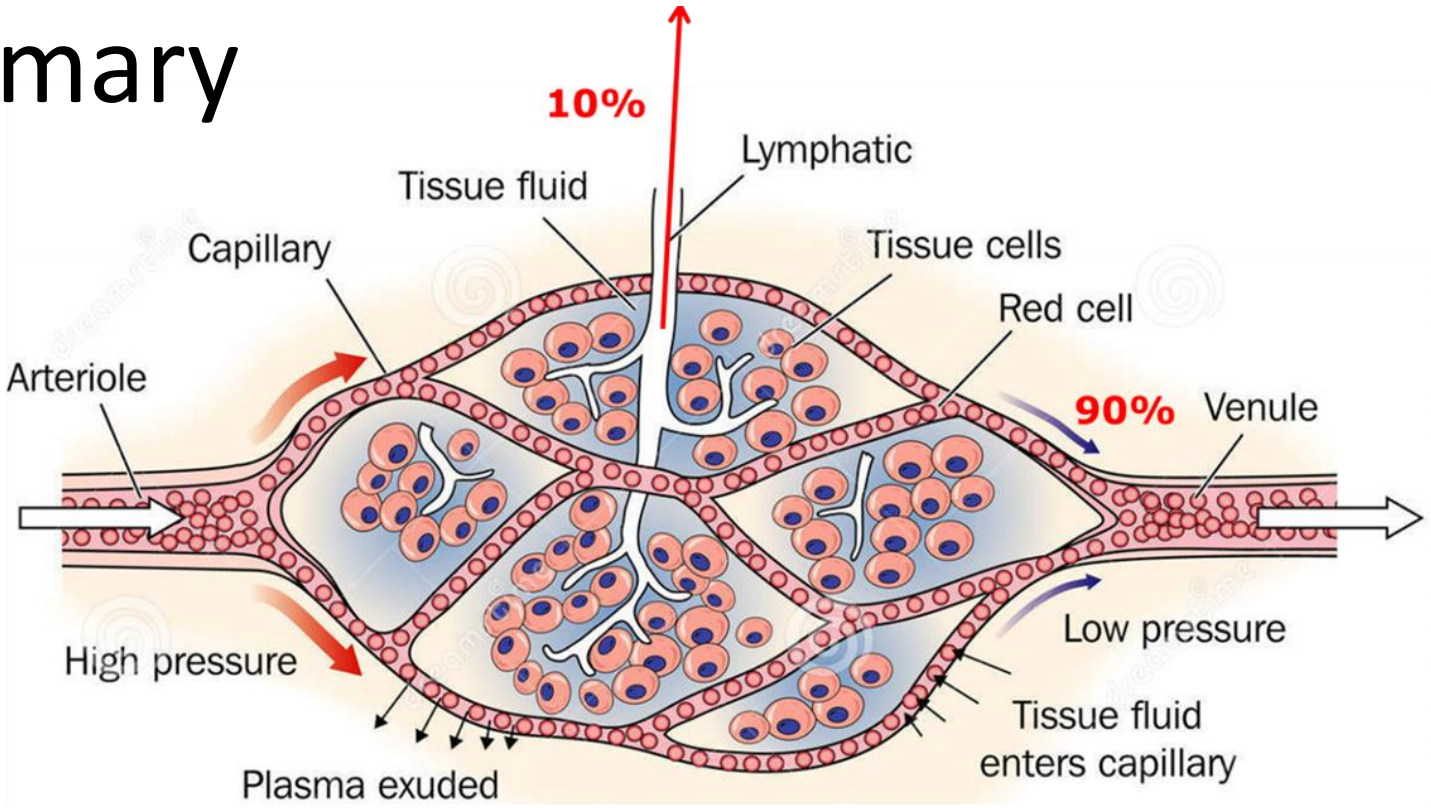
10% moves into lymphatic vessels and becomes **lymph**

→ Lymph is returned to blood via the subclavian veins near heart





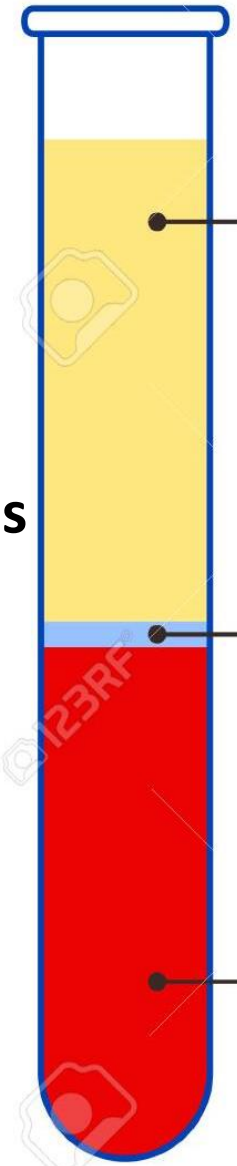
Summary



	Plasma	Tissue fluid	Lymph
Cells	None (RBCs and WBCs are not included in plasma)	Some phagocytes, no platelets	Lymphocytes
Plasma proteins	Present	Only smaller proteins present	Present
Location	Within heart, arteries, veins and capillaries	Outside vessels, bathing cells	Within lymph vessels
Function	Transport substances in blood	Medium of exchange, maintains homeostasis	Drain excess fluid, defense against pathogens

Components of Blood

Blood that is centrifuged

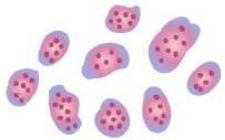


55% **Plasma**

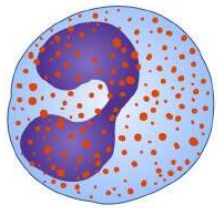
- **Water** (good solvent, high specific heat capacity)
- **Ions**
- **Proteins**
- **Nutrients** (e.g. glucose, amino acids, lipid)
- **Wastes** (e.g. urea)
- **Gases** (e.g. CO_2, O_2)

1%

- **Platelets**



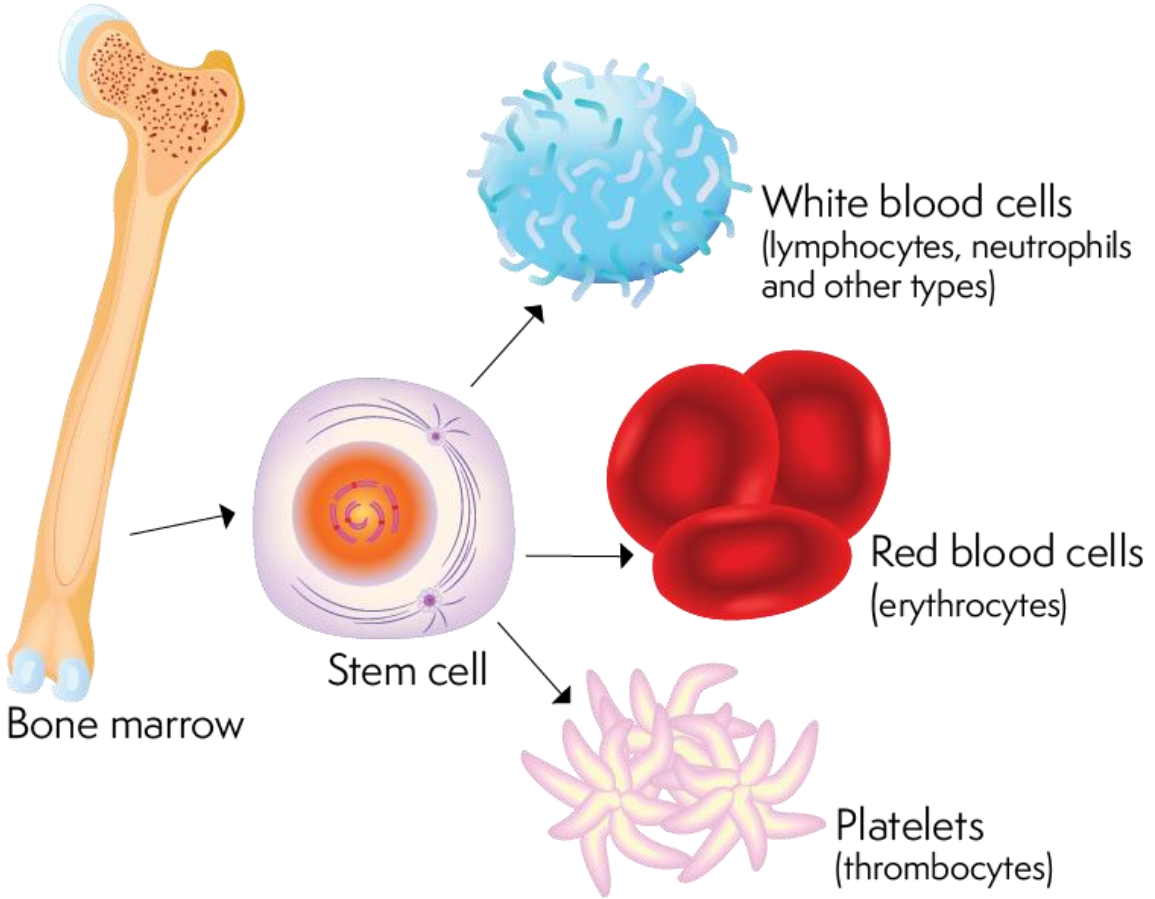
- **White blood cells**



44% **Red blood cells**

WBCs and RBCs

- Both made in the **bone marrow**
- From same type of stem cells

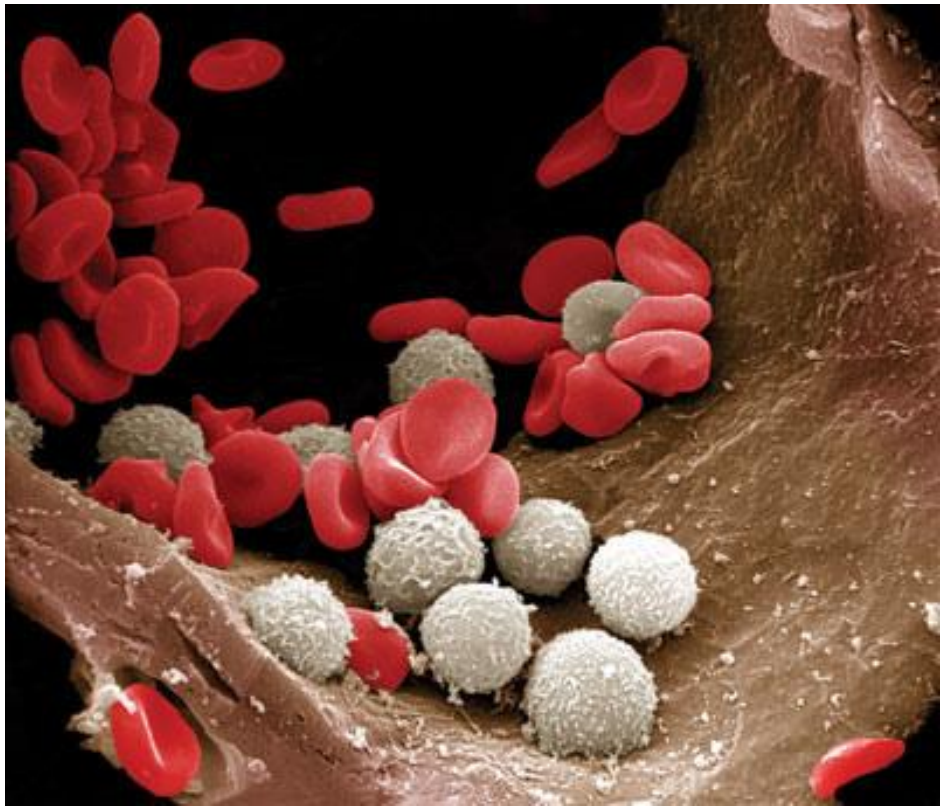


White Blood Cells

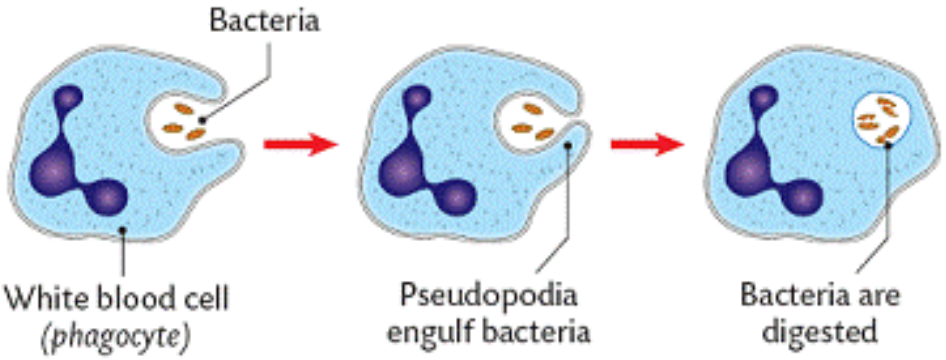
- Aka **leucocytes**
- Made in **bone marrow**
- Function: **fighting diseases**

2 types of WBCs:

1) **Phagocytes**
2) **Lymphocytes**



1) Phagocytes

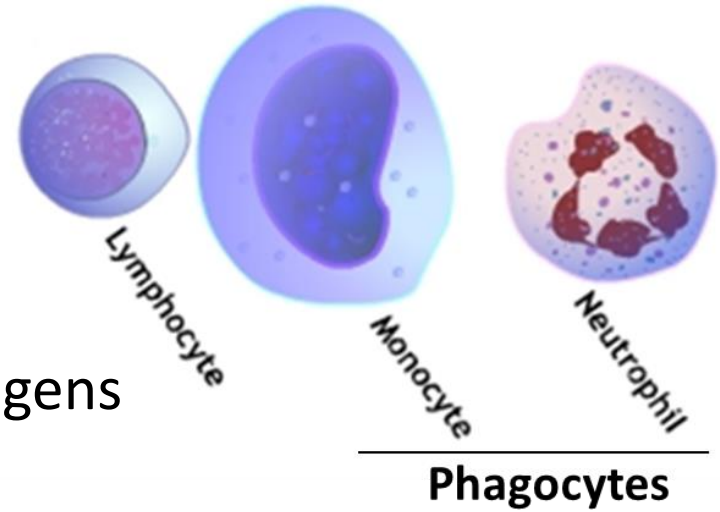


- Produced throughout life

Function:

- Patrol in blood, tissues and organs
- Remove dead cells and pathogens

→ By **phagocytosis** (Chap 4)



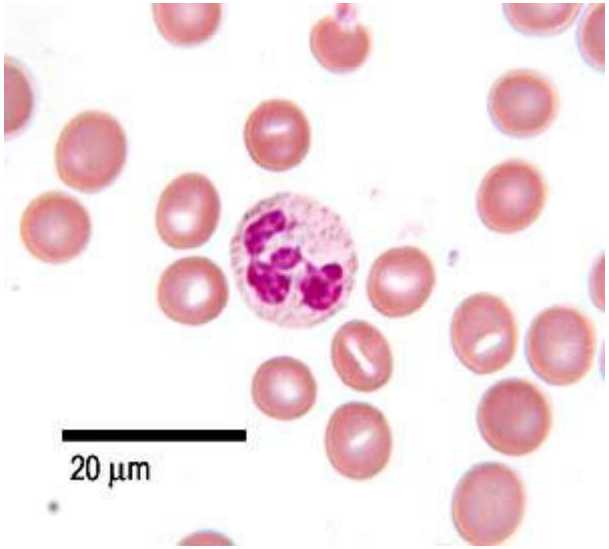
- Involved in **non-specific defense**

→ responds to many different non-self antigens

Appearance:

- **Lobed nuclei**
- **Granular cytoplasm** – due to many vesicles

1) Phagocytes



E.g. Neutrophils

- **Multi-lobed nucleus**
- Have **receptor proteins** on its membrane

→ **To identify pathogens as non-self**

- When there is an infection, large numbers are released from bone marrow

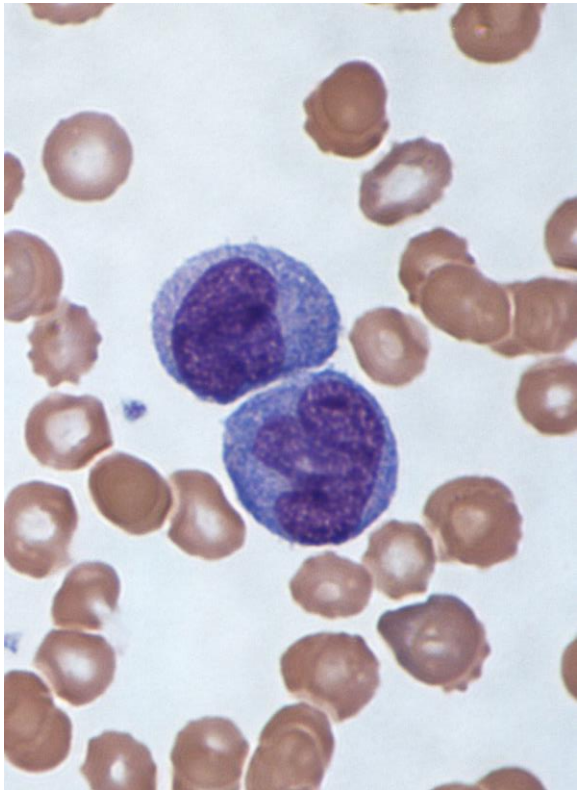
→ **Accumulate at site of infection**

- Short-lived (few hours-days)

→ Dies after digesting pathogens

→ Dead neutrophils form pus :O

1) Phagocytes



E.g. Monocyte → Macrophage

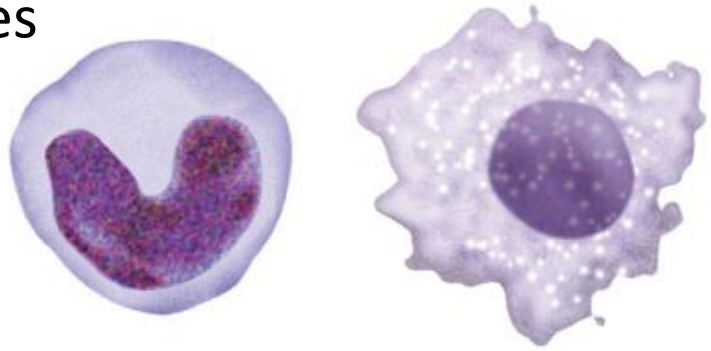
- **Lobed nucleus** / kidney-bean shaped
- Larger than neutrophils
- Have **receptor proteins** on its membrane

→ **To identify pathogens as non-self**

- Monocytes = circulate in blood

→ Mature into macrophages when it leaves blood and enter organs

- Long-lived cells
- Macrophages found in organs such as liver, lungs, spleen, kidney, lymph nodes



2) Lymphocytes

- Produced in bone marrow before birth

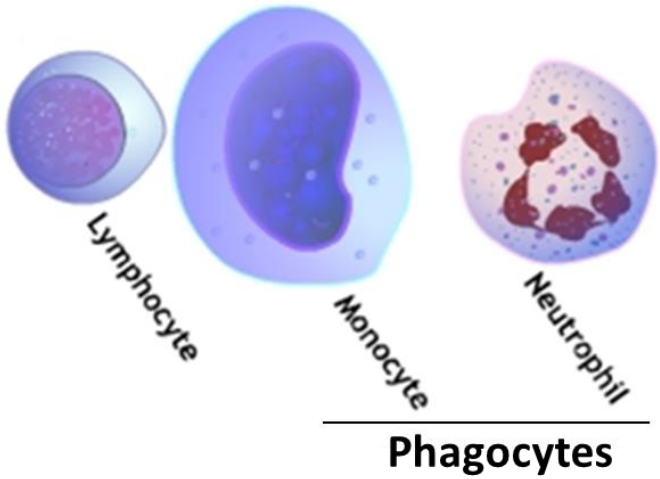
Function:

- Involved in **specific immune responses**

→ responds to only specific non-self antigens

- Mature lymphocytes circulate in the **blood and lymph**

→ **Accumulate at sites of infection**



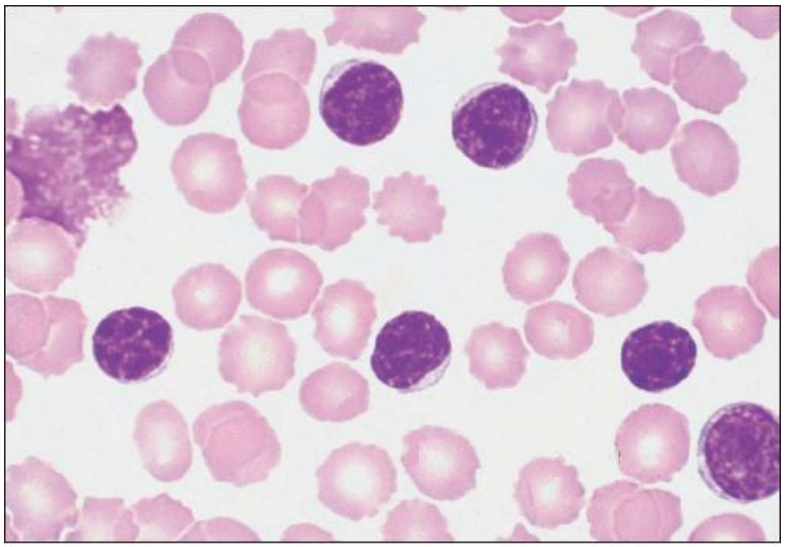
Appearance:

- **Smaller** than phagocytes
- **Large round nucleus**
- **Little cytoplasm**

2) Lymphocytes

2 main types:

Both made in **bone marrow,** but mature in different places and have different functions



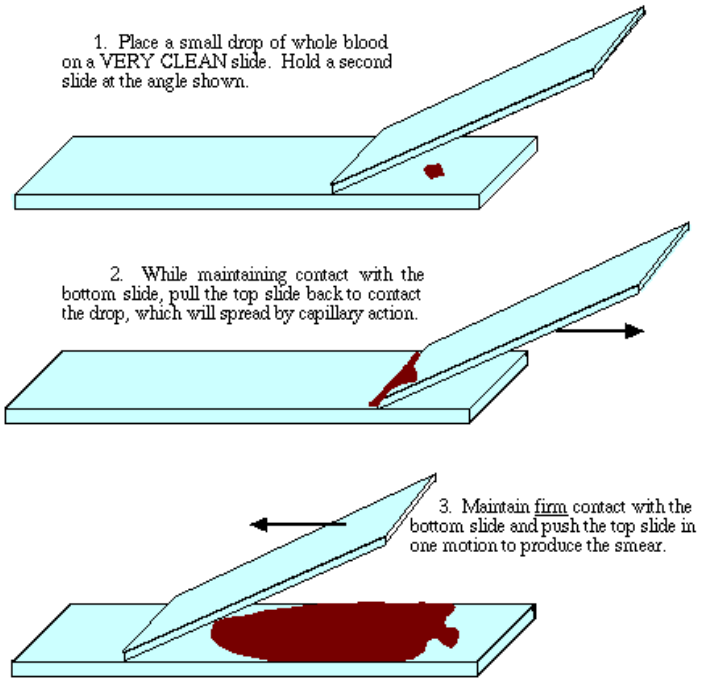
Source: Estella Matutes, Barbara J Bain, Andrew Wotherspoon
Lymphoid Malignancies: An Atlas of Investigation and Diagnosis
Copyright © Evidence Based Networks Ltd.

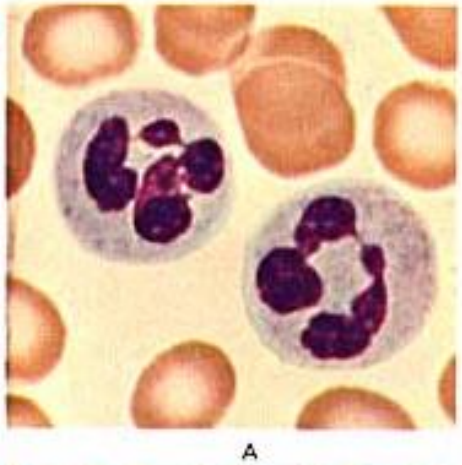
1. **B-lymphocytes (B cells)**
   - Mature in **bone marrow**
   - **Produces antibodies**

2. **T-lymphocytes (T cells)**
   - Mature in **thymus**
   - Does **NOT** produce antibodies

- Both work together to defend the immune system

Blood Smear


1. Place a small drop of whole blood on a VERY CLEAN slide. Hold a second slide at the angle shown.
2. While maintaining contact with the bottom slide, pull the top slide back to contact the drop, which will spread by capillary action.
3. Maintain firm contact with the bottom slide and push the top slide in one motion to produce the smear.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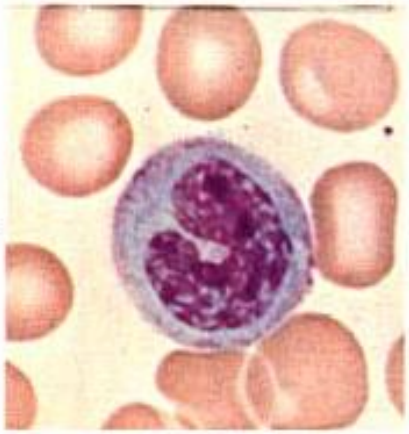

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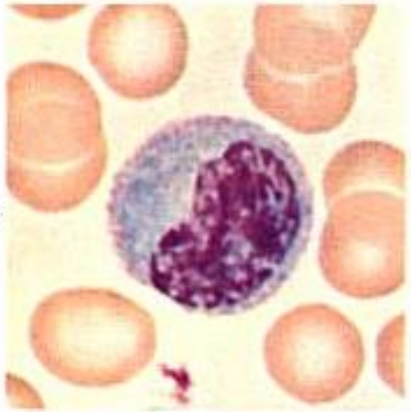
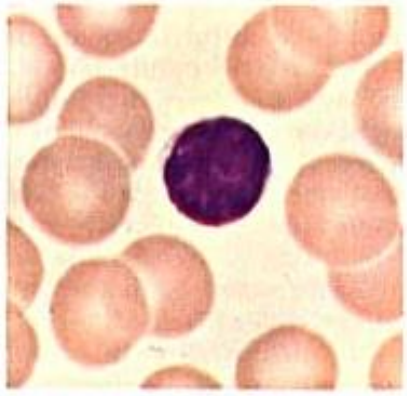
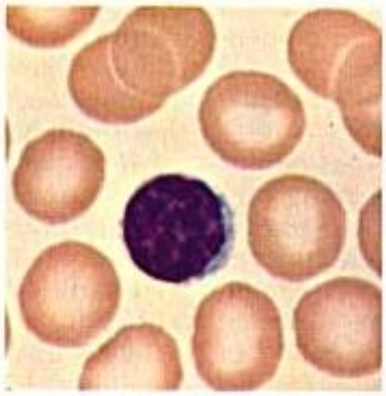
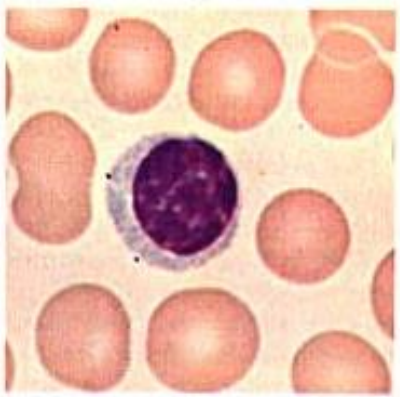
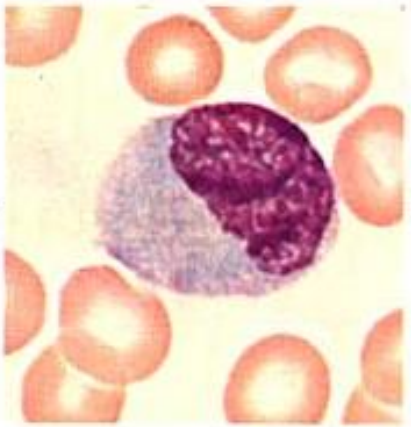










Differentiating WBCs from RBCs

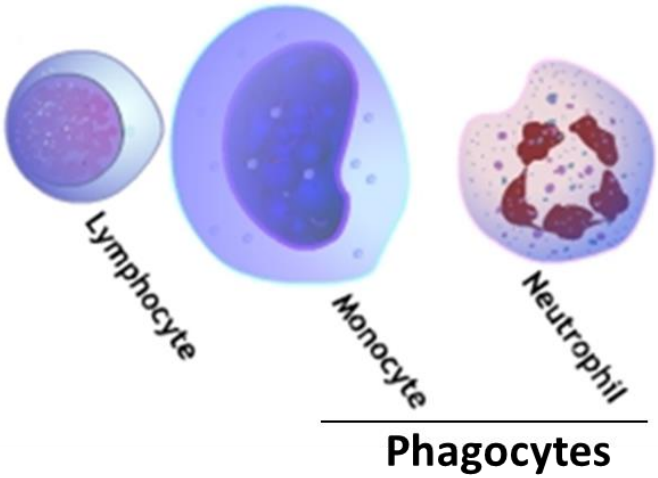
1) Contains **nucleus**

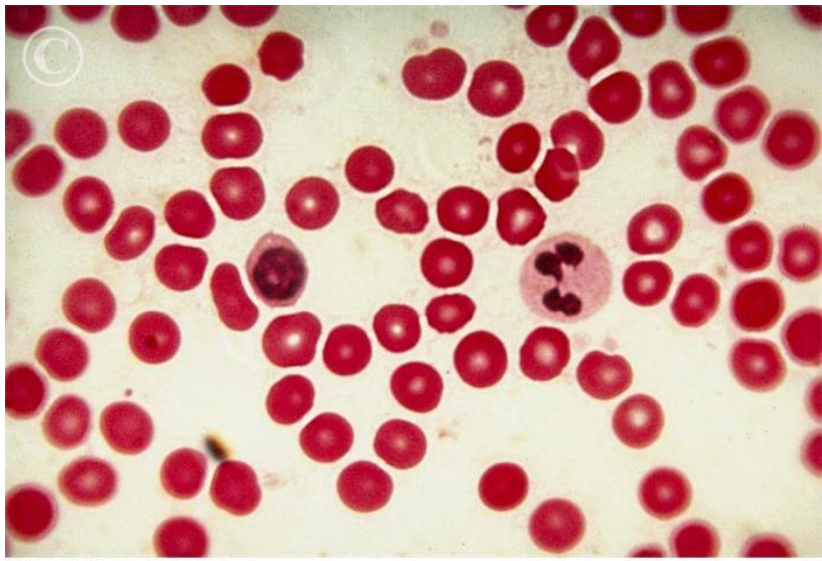
2) Mostly **larger** than erythrocytes (except for lymphocytes)

3) **Spherical / irregular** in shape

- Do not have a biconcave disc shape

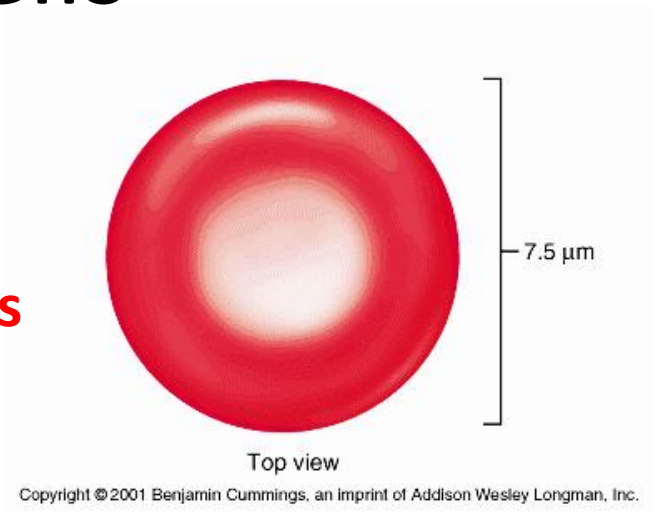
4) Phagocytes have **granular cytoplasm**





Red Blood Cells

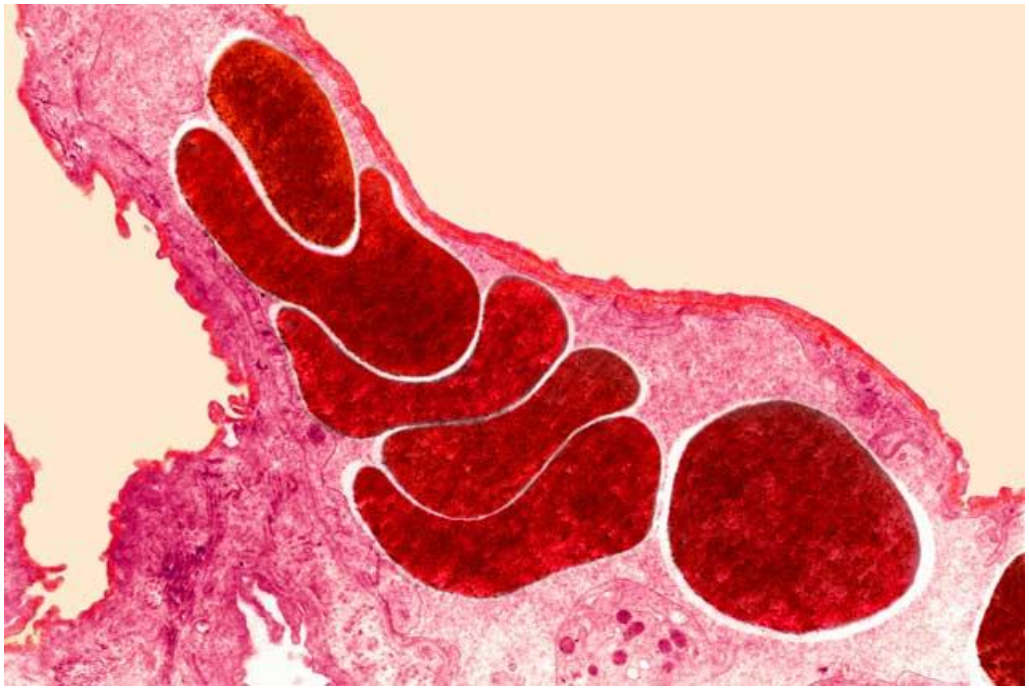
- Aka **erythrocytes**
- RBCs are short lived (120 days)
- Function: **transport oxygen to body tissues**



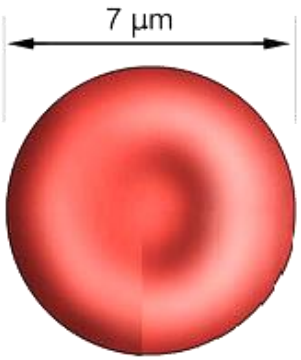
Features:

1) Small and flexible

- Diameter about **6-8µm**
- Able to squeeze through capillaries (7µm)
- Reduce diffusion distance



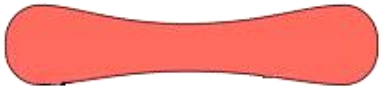
Red Blood Cells



Top View shows RBC to be circular

2) Biconcave Disc

- Increases surface area
- For diffusion of oxygen to cells

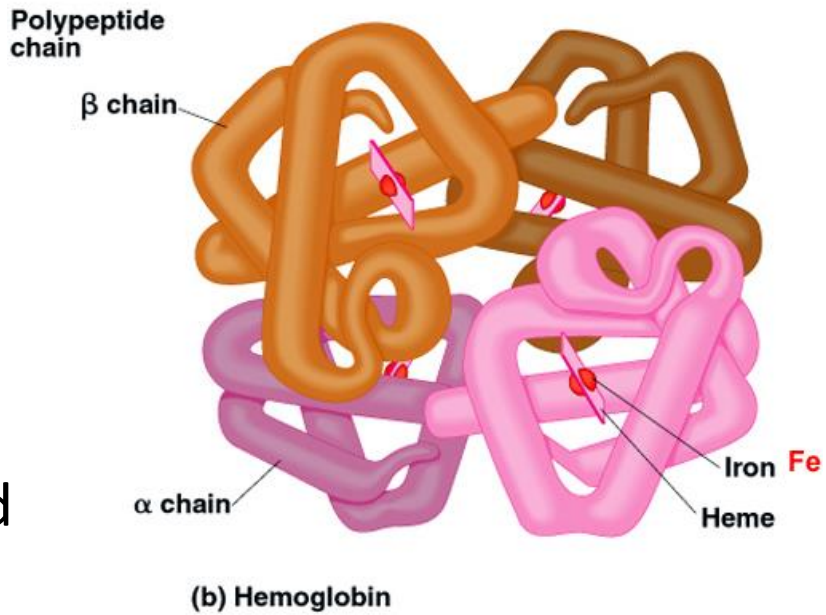


Side view shows RBC to be a biconcaved disc

3) No nucleus, no mitochondria, no ER

- More room for haemoglobin
- Maximise the number of oxygen carried by RBC

Haemoglobin



- Found in large quantities in RBC

- Globular protein
- Made of 2 alpha-globin chains and 2 beta-globin chains

→ Quaternary structure

- Each chain contains 1 haem group that has Fe^{2+}

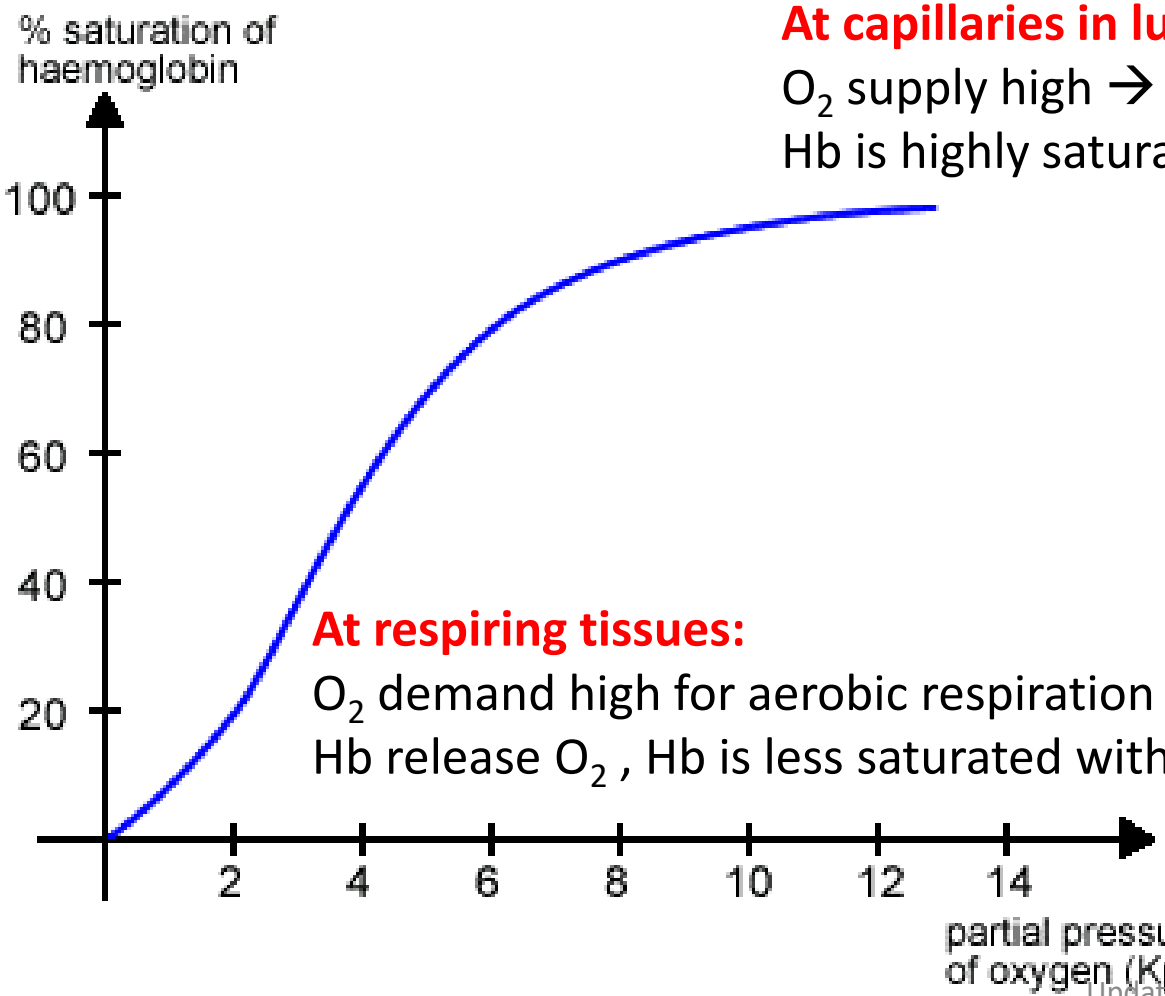
→ Binds 1 molecule of O_2 each

- Hb bind with oxygen to form **oxyhaemoglobin** in lungs
- $Hb + 4O_2 \rightarrow HbO_8$

Transport of O_2 and CO_2

The Haemoglobin Dissociation Curve

As partial pressure of oxygen (pO_2) increases, percentage saturation of haemoglobin with oxygen increases



At capillaries in lungs:

O_2 supply high → so **pO_2 is high**

Hb is highly saturated with O_2

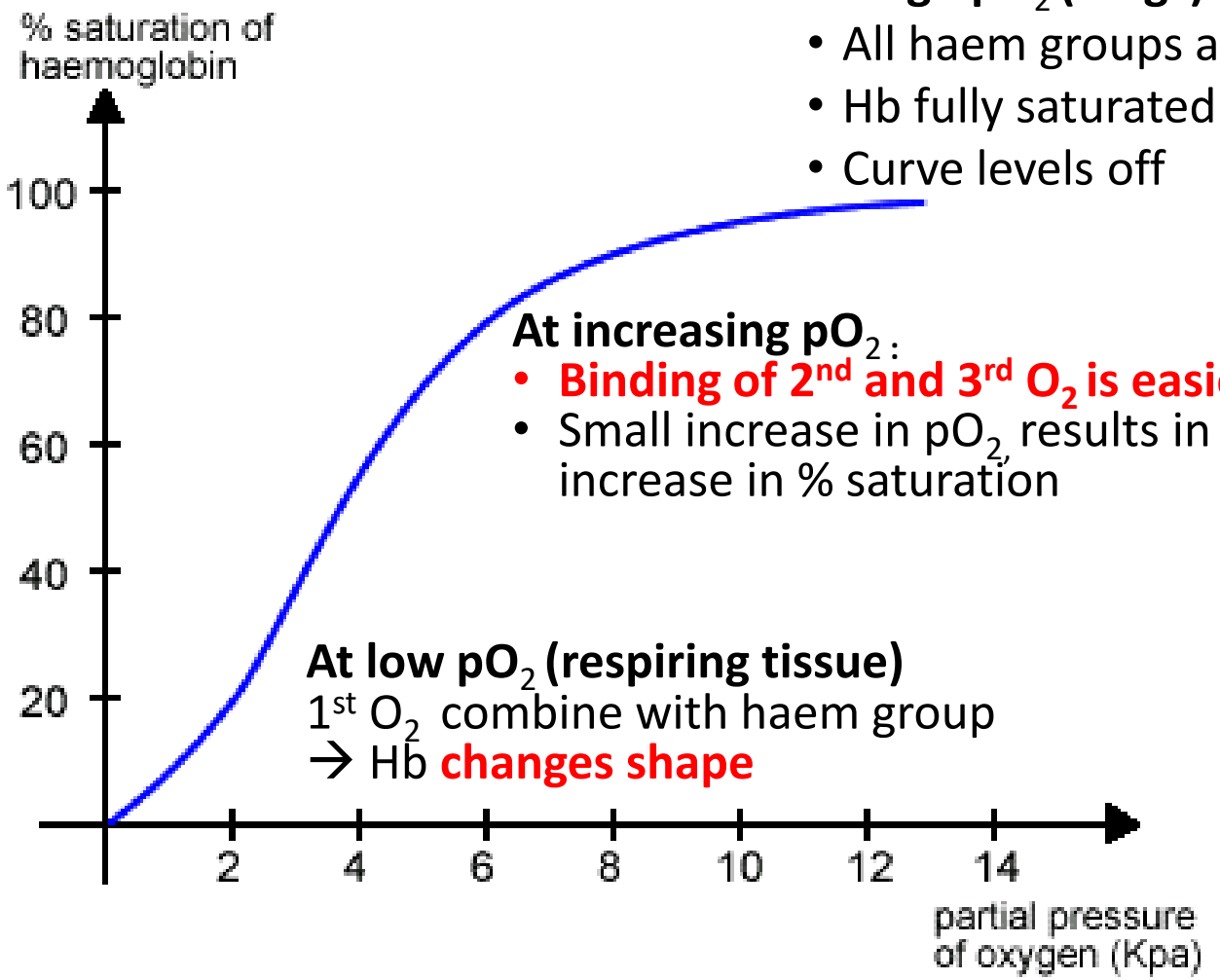
At respiring tissues:

O_2 demand high for aerobic respiration →so **pO_2 is low**

Hb release O_2 , Hb is less saturated with O_2

Why is the curve S-shaped?

Hemoglobin exhibits **cooperative binding / allosteric effects**, as oxygen binding increases the affinity of hemoglobin for more oxygen!



At high pO_2 (lungs)

- All haem groups are fully occupied
- Hb fully saturated
- Curve levels off

At increasing pO_2 :

- **Binding of 2nd and 3rd O_2 is easier than 1st**
- Small increase in pO_2 results in large increase in % saturation

At low pO_2 (respiring tissue)

1st O_2 combine with haem group

→ Hb **changes shape**

Why is this important?

- pO_2 in lungs are higher
- **pO_2 in respiring tissues are lower**

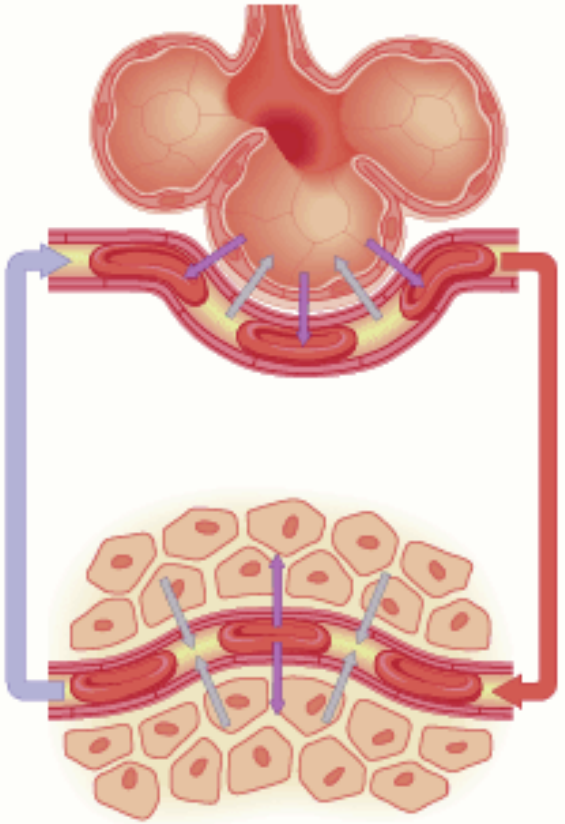
As blood travel from capillaries in lungs to tissues:

- Small decrease in partial pressure leads to a large decrease in % saturation

→ Allows **more oxygen to be released** / dissociate from Hb

→ **Affinity of Hb to oxygen decreases** at low pO_2

At lungs:
O2 supply high
Bind O2
pO2 high, %saturation high

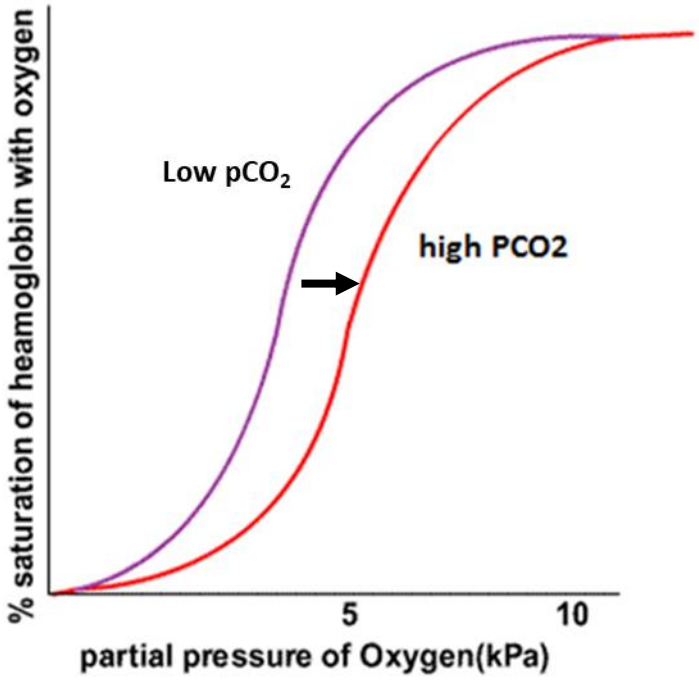


At respiring tissues:
O2 demand high for aerobic respiration
Release O2
pO2 low, %saturation low

Factors that affect affinity of Hb to O_2

- **pO_2** – High pO_2, **increases** affinity of Hb to O_2

- **pCO_2** – High partial pressures, **decreases** affinity of Hb to O_2
  → Result in the **Bohr effect / Bohr shift**
  → Where the curve shifts to the right



The Bohr Effect

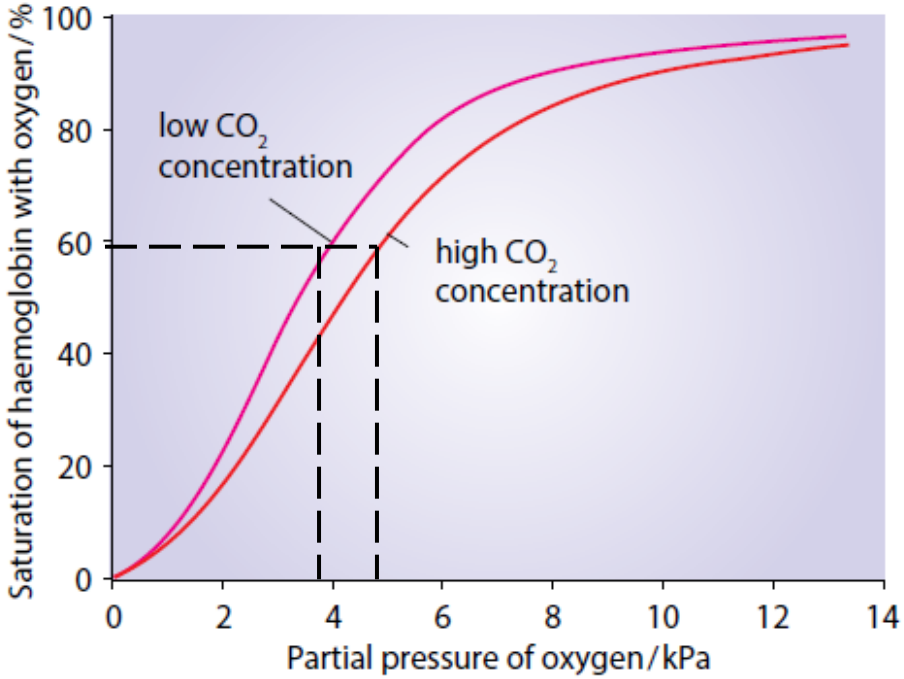
Christian Bohr, 1904

- Where the affinity of Hb to O_2 is affected by pCO_2
- High pCO_2 **decreases** affinity of Hb to O_2

→ Therefore a higher pO_2 is needed to meet the same % saturation

→ The curve shifts to the right

- Bohr effect **increases dissociation of oxyhaemoglobin in actively respiring tissues**



The Bohr Effect

Lung tissues have

- Higher pO_2 , **Lower pCO_2**

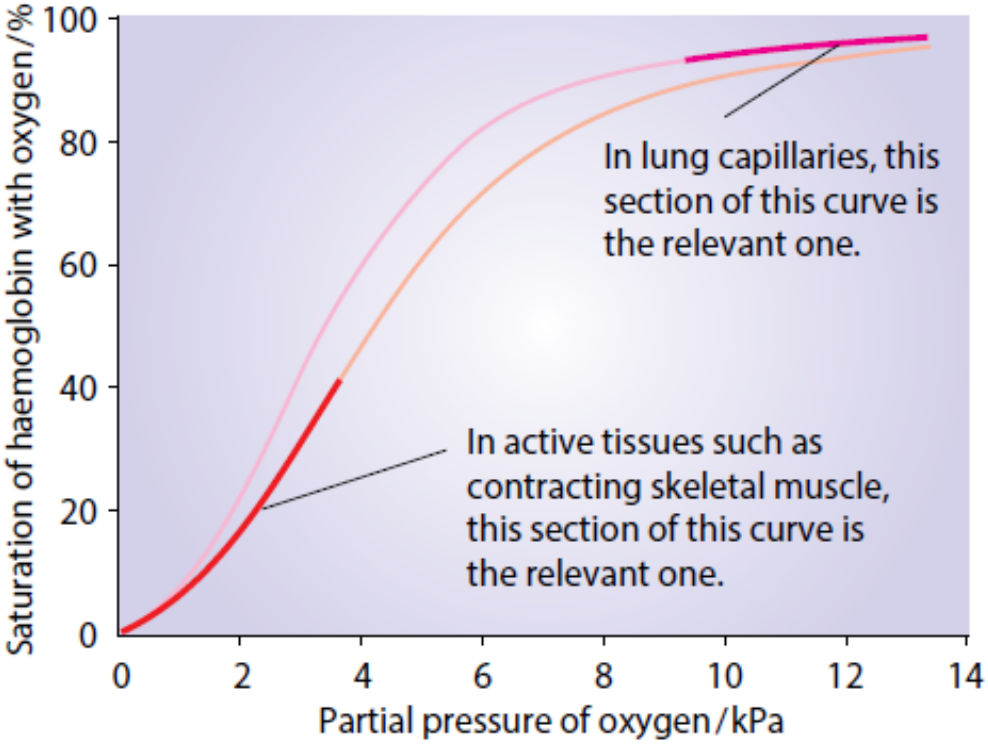
Respiring tissues have

- Lower pO_2, **Higher pCO_2**

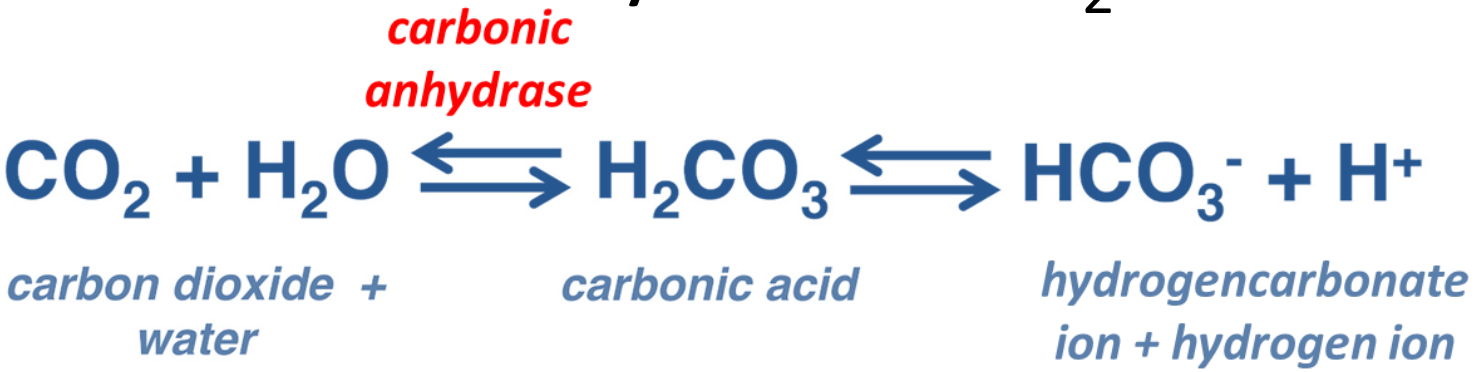
→ oxyhaemoglobin dissociates more readily

→ more oxygen to meet the demand for aerobic respiration

The effect of changes in carbon dioxide concentration on oxygen transport



How does high pCO_2 decrease the affinity of Hb to O_2 ?



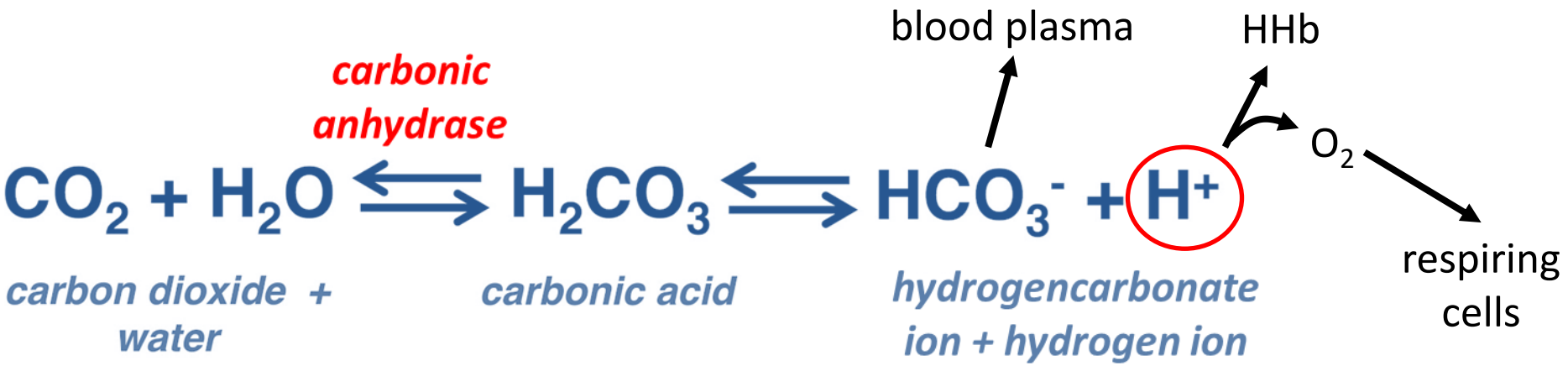
1. CO_2 diffuses from respiring tissue → blood plasma → RBC

2. **Carbonic anhydrase** in cytoplasm of RBC converts CO_2 to **carbonic acid**

   → This maintains a steep concentration gradient for diffusion of carbon dioxide from tissues to blood

3. Carbonic acid **dissociates** into **hydrogencarbonate ions and hydrogen ions**

   → decrease in pH

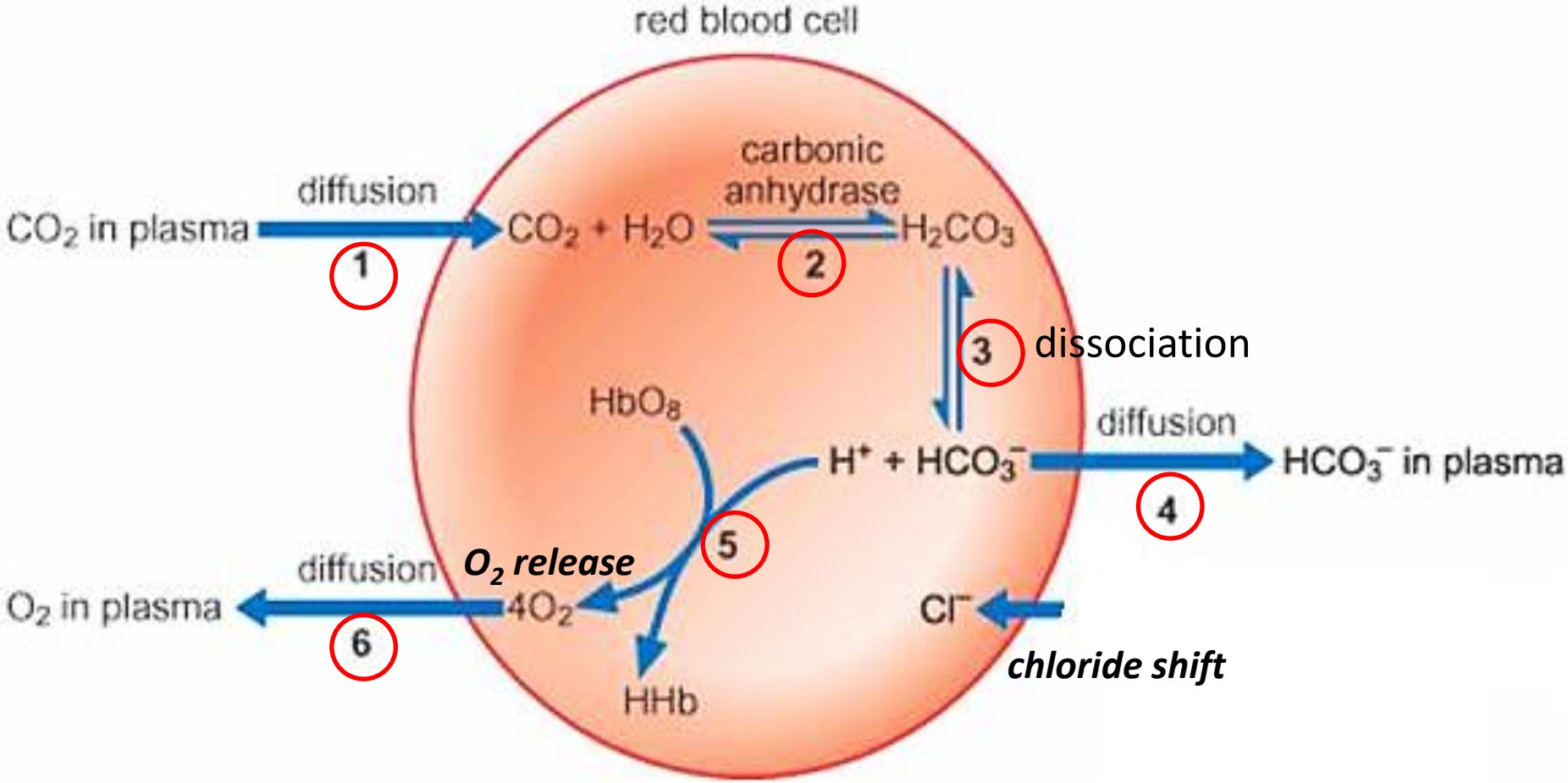


4. HCO_3^- diffuse from RBC → blood plasma
   Cl^- move into RBC to balance out negative charge (**chloride shift**)

5. H^+ combines with Hb to form **haemoglobinic acid** (HHb)
   → Hb has higher affinity for H^+ than oxygen
   → H^+ lowers affinity of Hb for oxygen
   → HHb also prevents pH from decreasing / acts as buffer

6. **Hb releases oxygen**
   O_2 diffuses from RBC → blood plasma → **respiring cells**

Numbers circled correspond to the steps in previous slides!

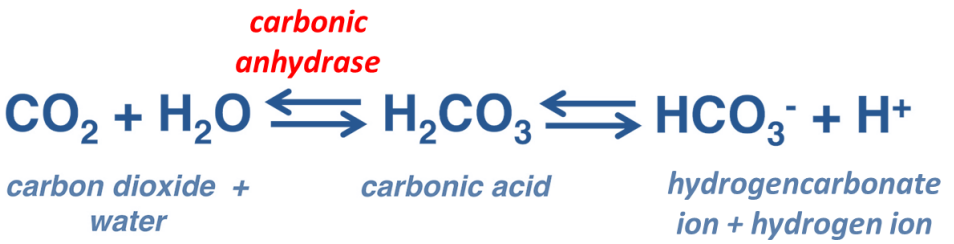


CO_2 is only transported in the form of hydrogencarbonate ions only **85%** of the time!!!

Transport of CO_2 from Respiring Tissues

85% Hydrogencarbonate ions

- Carbonic anhydrase converts CO_2 to carbonic acid
- Carbonic acid dissociates
- HCO_3^- diffuse from RBC into plasma

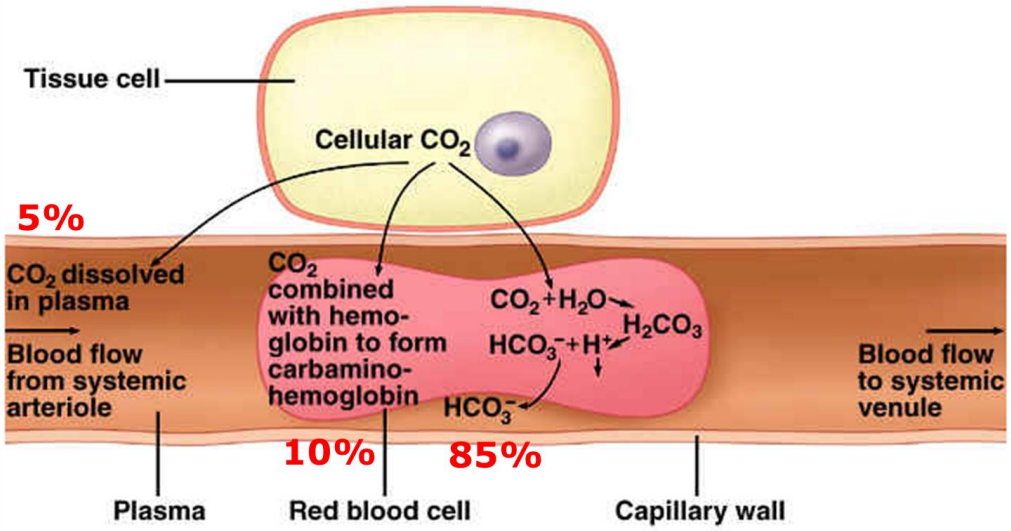

carbonic anhydrase
$CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons HCO_3^- + H^+$
carbon dioxide + water
carbonic acid
hydrogencarbonate ion + hydrogen ion

5% Dissolve in blood plasma

- Remains as CO_2 molecules

10% Carbaminohaemoglobin

- Diffuse into RBC
- **Bind to terminal amine of Hb**
- Form **carbaminohaemoglobin**



Transport of CO_2 to Lungs

- **Low pCO_2 , high O_2 in alveoli**
- Processes are reversed!

- HHb releases its H^+ ion binds O_2
  → forms **oxyhaemoglobin**

1. Hydrogencarbonate ions diffuses back into RBC

→ Binds with H^+ and converted back into carbonic acid

→ Carbonic acid converted back to CO_2 + H_2O

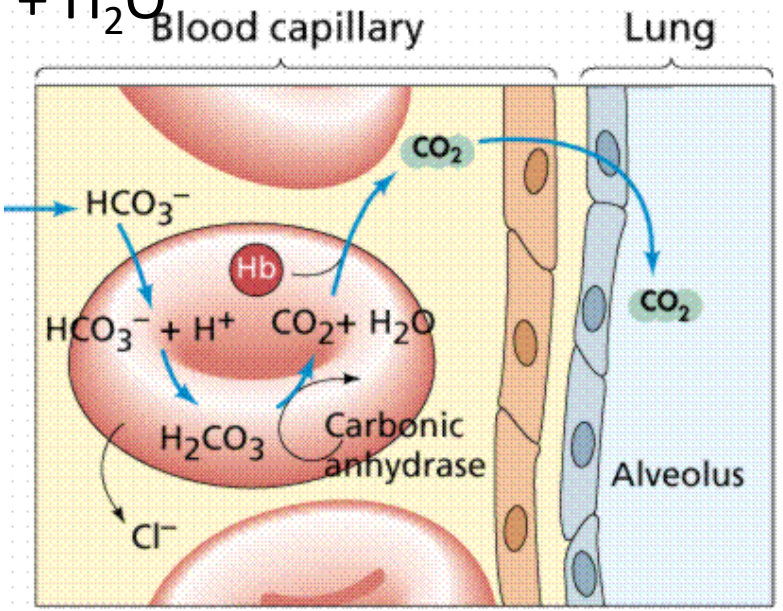
→ **Diffuse into alveoli**

2. Dissolved CO_2 in blood plasma

→ **Diffuse into alveoli**

3. CO_2 from carbaminohaemoglobin

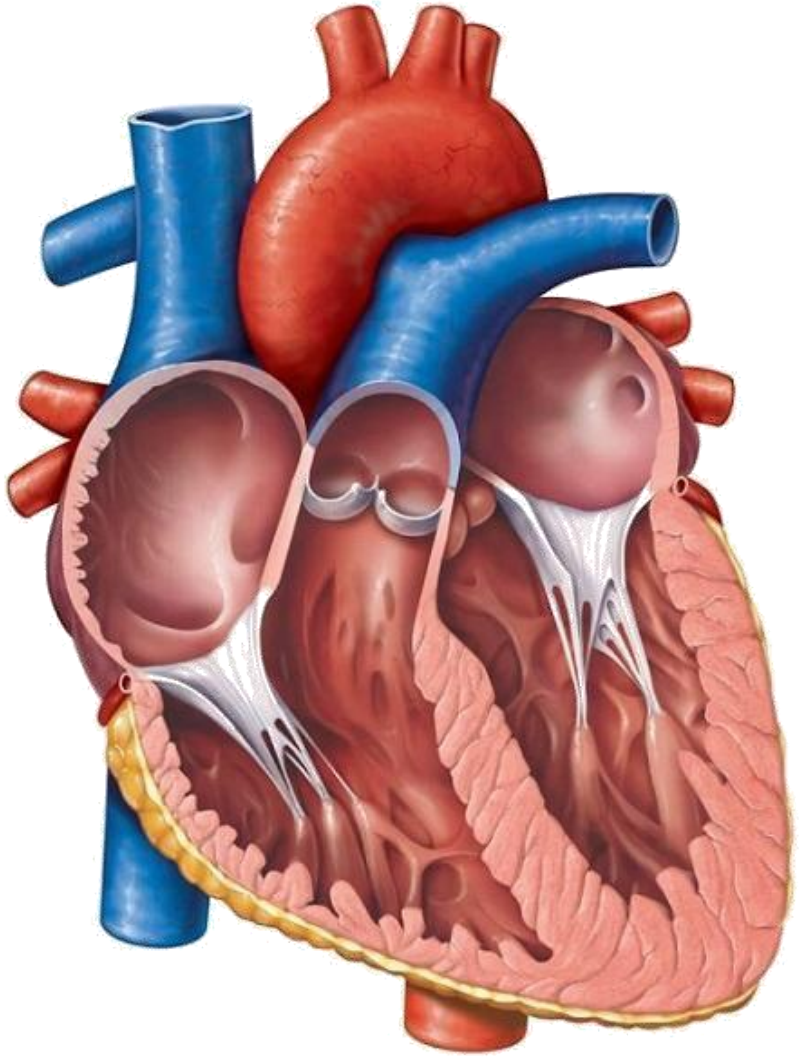
→ **Diffuse into alveoli**



The Heart

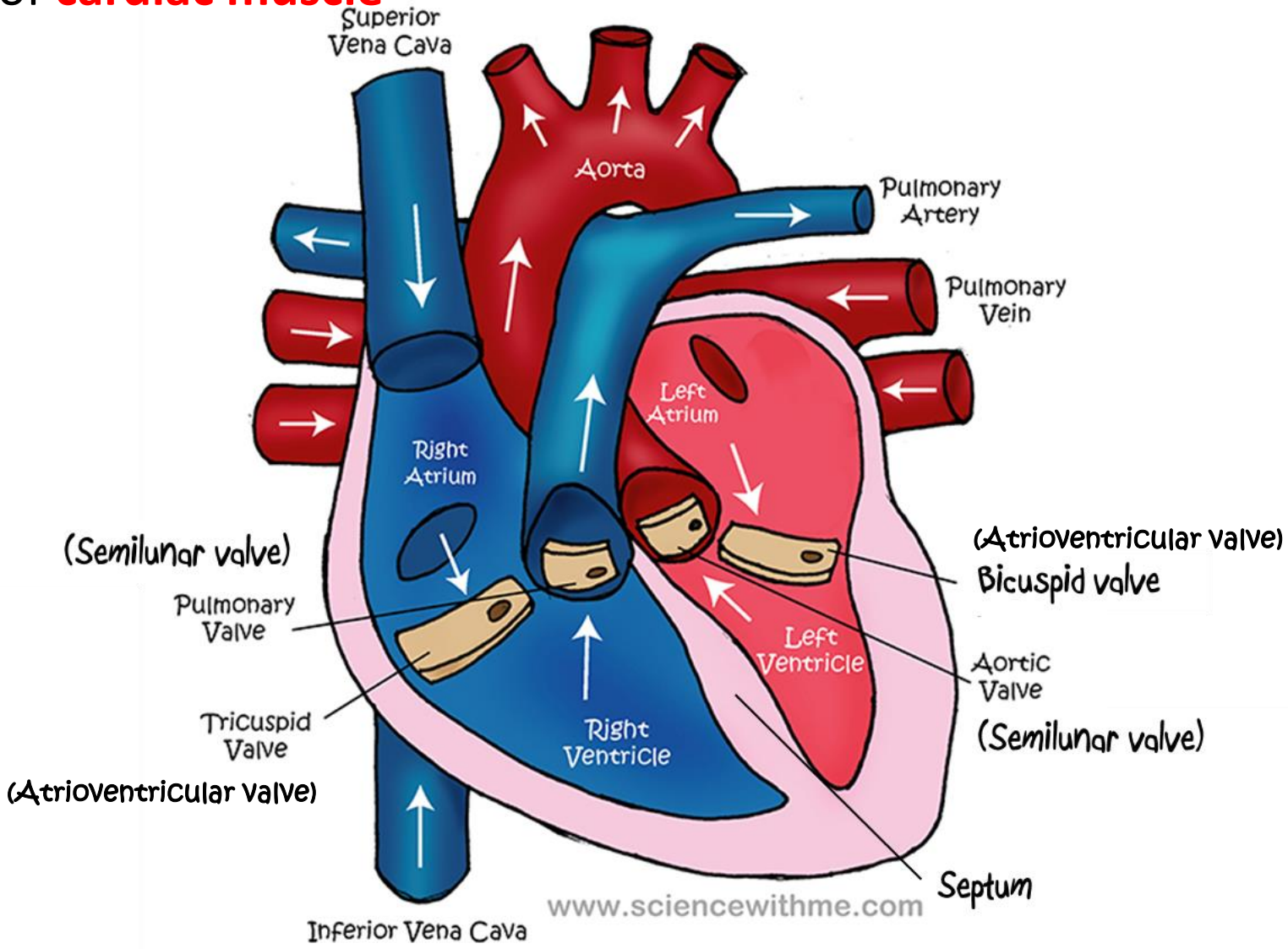
Chapter Outline

- Structure of the heart
- The Cardiac Cycle
  - Atrial Systole
  - Ventricular Systole
  - Diastole
  - Blood Pressure
- Control of heart beat
  - Sinoatrial node (SAN)
  - Atrioventricular node (AVN)
  - Purkyne/Purkinje tissue



Structure of the Heart

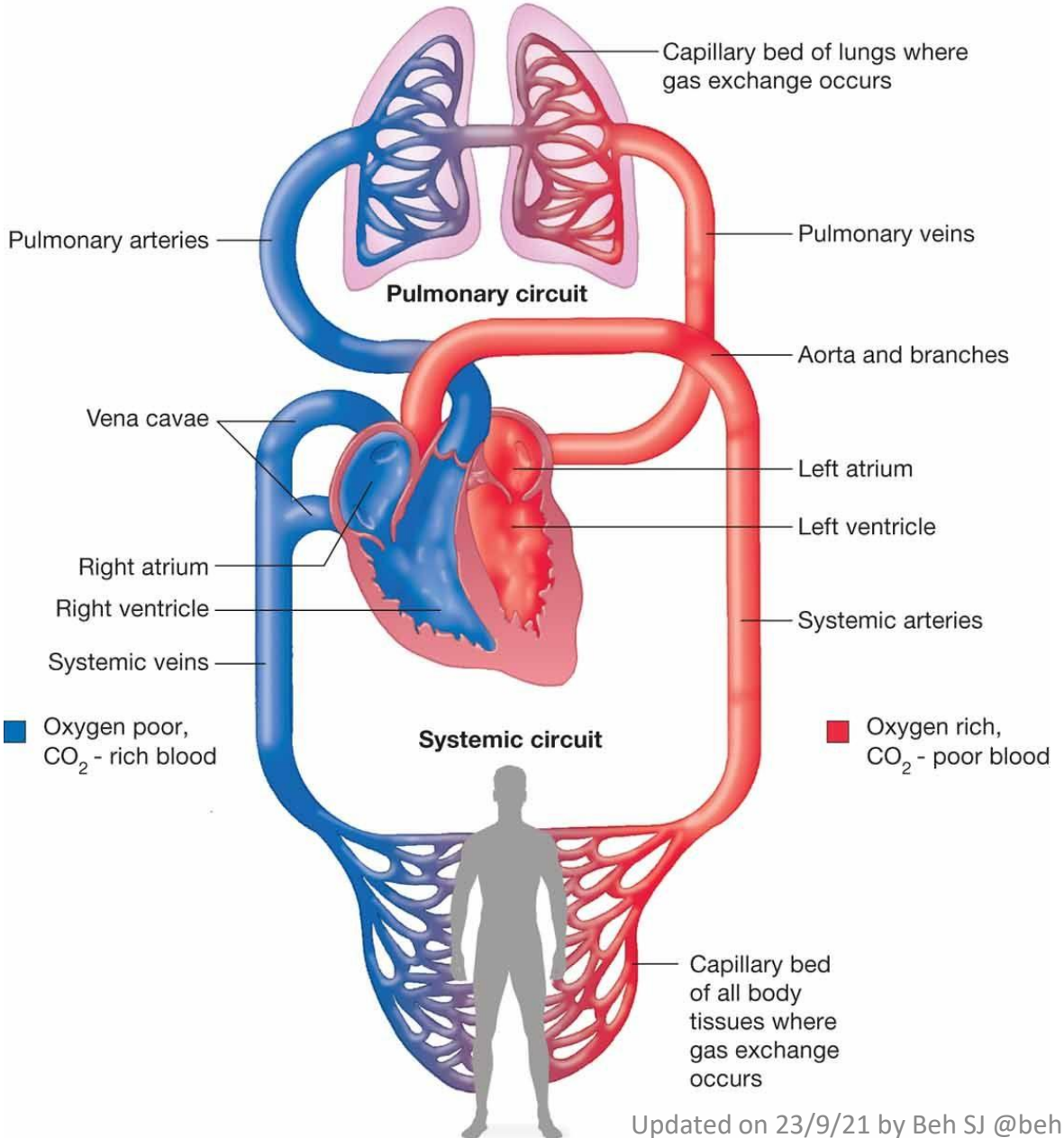
- Made of **cardiac muscle**



Structure of the Heart

Blood **passes through the heart twice**, in one complete circuit

→ Closed, double circulatory system



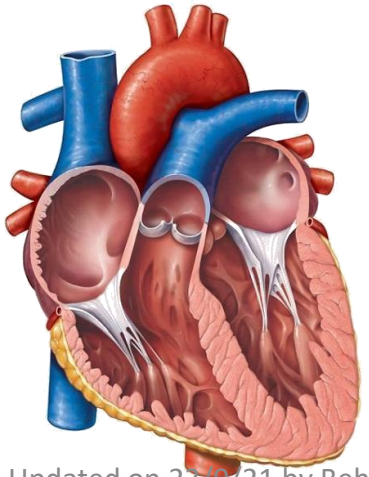
Structure of the Heart

The walls of the ventricles are thicker than atria walls. WHY?

- Because ventricles need high force to pump blood to the whole body

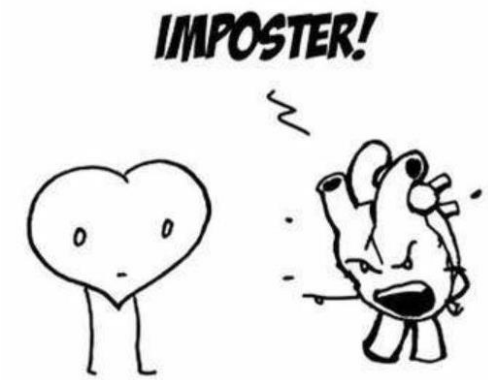
The left ventricle has a thicker wall than the right. WHY?

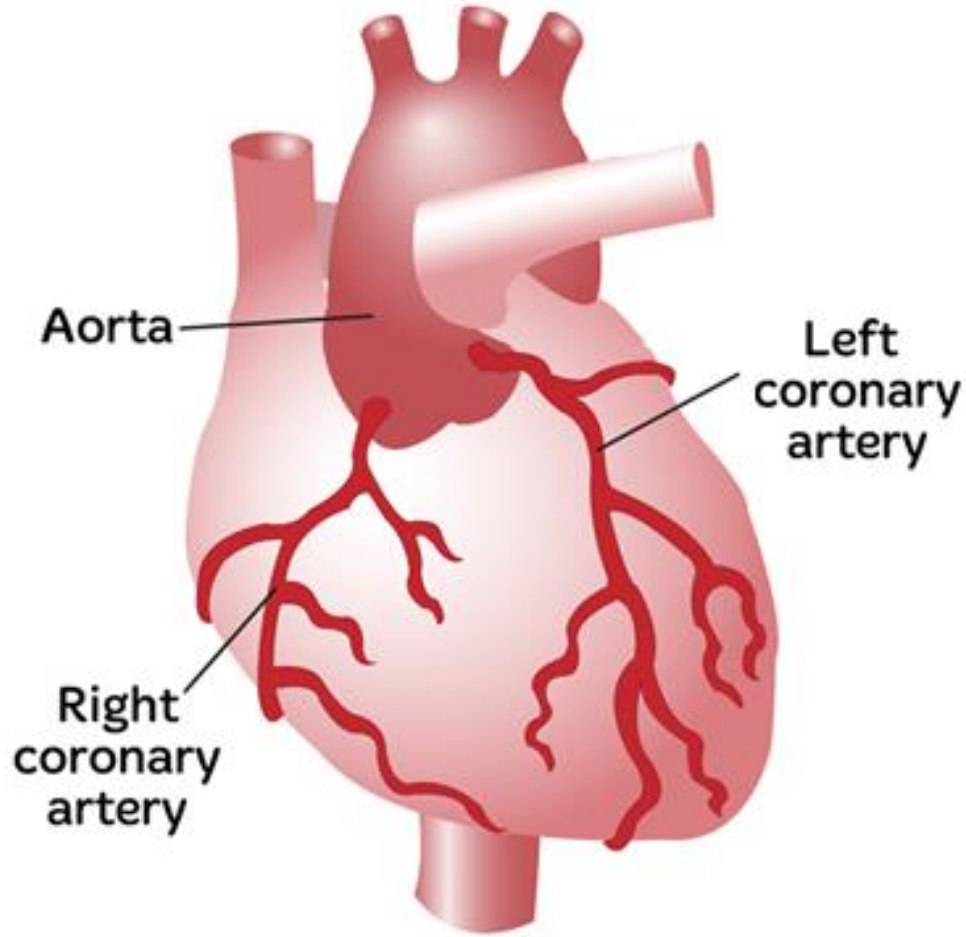
- Because the right ventricle only pumps blood to the lungs, left ventricles pumps blood to the entire body
- If the right ventricle pumps with too high pressure, tissue fluid may accumulate in lungs



Structure of the Heart

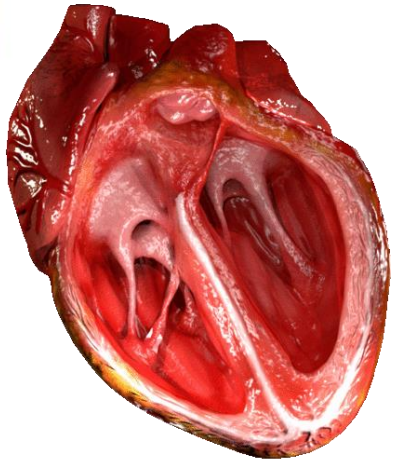
- **Coronary arteries** = the blood vessels that supply cardiac muscle with oxygenated blood





The Cardiac Cycle

- Normal heart rate is ~**75 beats per minute** (bpm)
- Average length of one cardiac cycle is **0.8s**

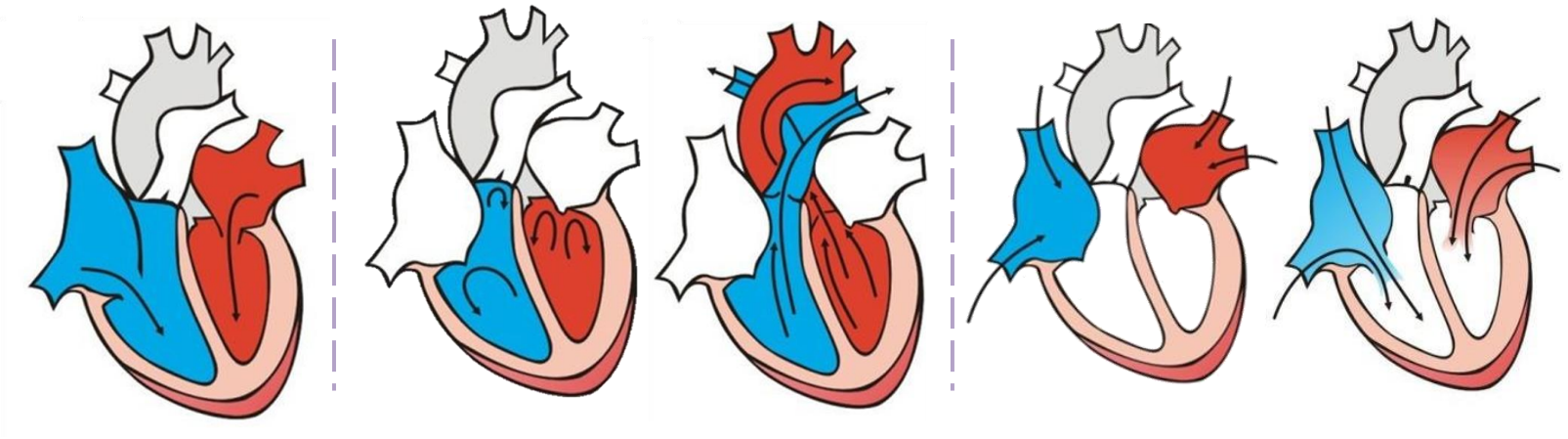


- 3 stages in the cardiac cycle:

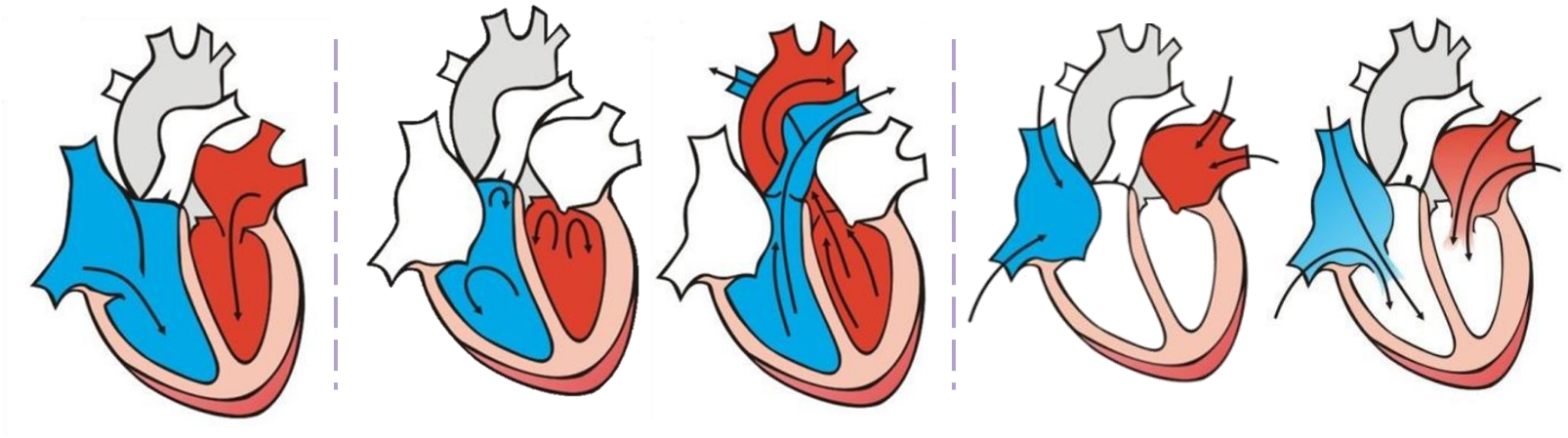
1) **Atrial systole**
2) **Ventricular systole**
3) **Diastole**

Systole = contraction/pumping

Diastole = relaxation/filling



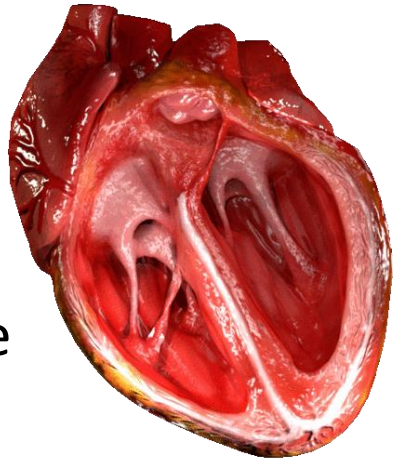
	Atrial Systole	Ventricular Systole	Diastole
Length (s)	0.1	0.3	0.4
What happens?	**Atria contract**	**Ventricles contract**	-
	Ventricles relax	Atria relax	**Atria and ventricles relax**
Valves that are open	Atrioventricular valves	Semilunar valves	Valves in vena cava and pulmonary veins, atrioventricular valves
Blood flows from…	Atria	Ventricles	Vena cava and pulmonary veins
Blood flows to…	Ventricles	Aorta and pulmonary artery	Atria and trickles into ventricles
Valves that are closed	Valves in vena cava and pulmonary veins, semilunar valves	Atrioventricular valves (produces “lub” sound)	Semilunar valves (produces “dub” sound)



Differences in pressure in atria, ventricles and arteries directly cause valves to open/close!

	Atrial Systole	Ventricular Systole	Diastole
What happens?	**Atria contract** Ventricles relax	**Ventricles contract** Atria relax	- **Atria and ventricles relax**
Atrial Pressure	**Atrial pressure > Ventricular pressure**	Much lower than ventricular pressure	Low, but increasing as blood fills heart
Ventricular Pressure	Lower than atrial pressure but increasing as blood fills heart	**Ventricular pressure > Atrial pressure** High, rapidly increasing.	Low, but increasing as blood fills heart
Pressure in Arteries	High, but slowly decreasing as blood flows to entire body	High, also rapidly increasing as blood is pumped through aorta	**Pressure in arteries > Ventricular pressure** High, but slowly decreasing as blood flows to entire body

Changes in Blood Pressure in Atria, Ventricles and Arteries

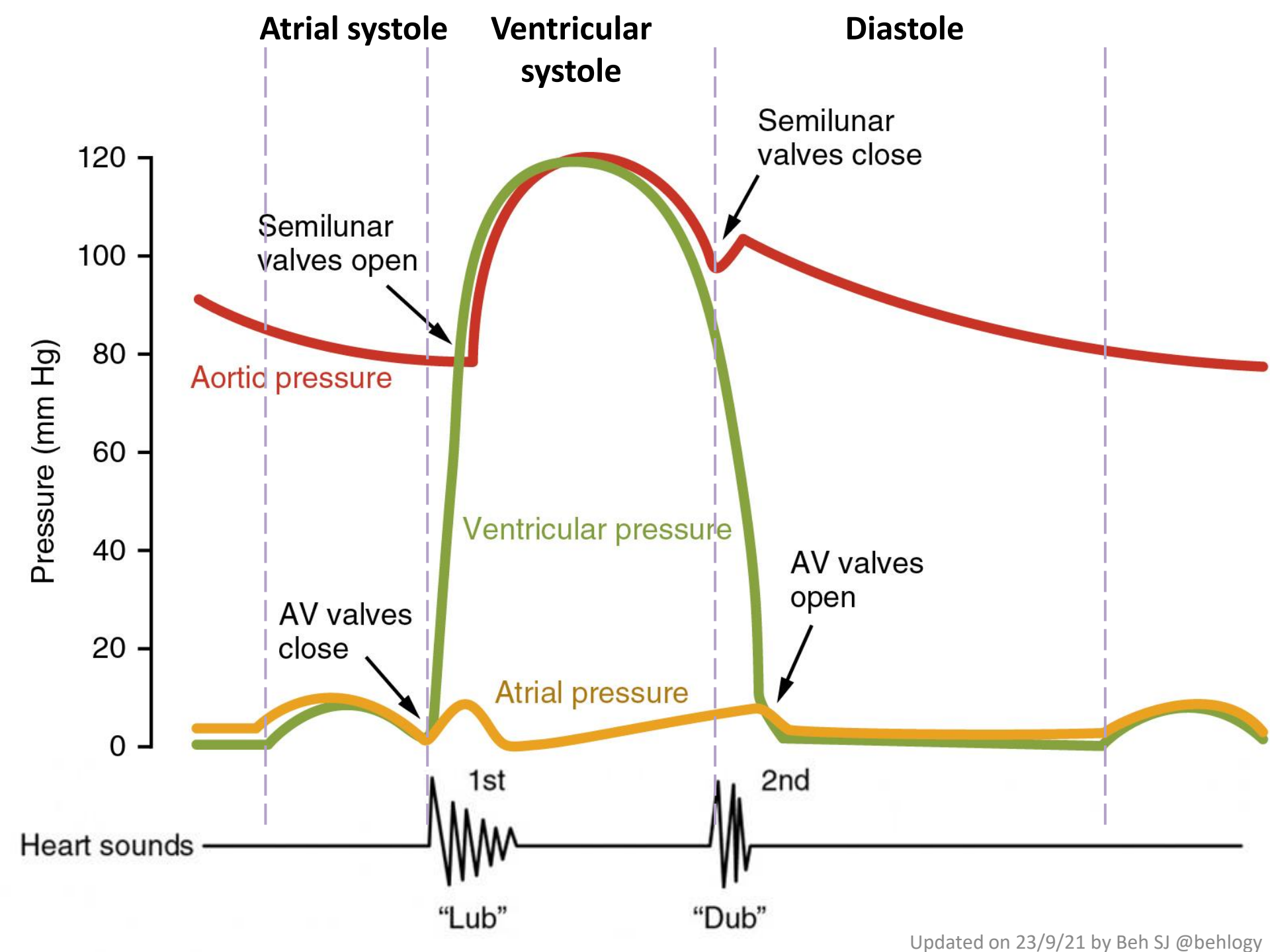


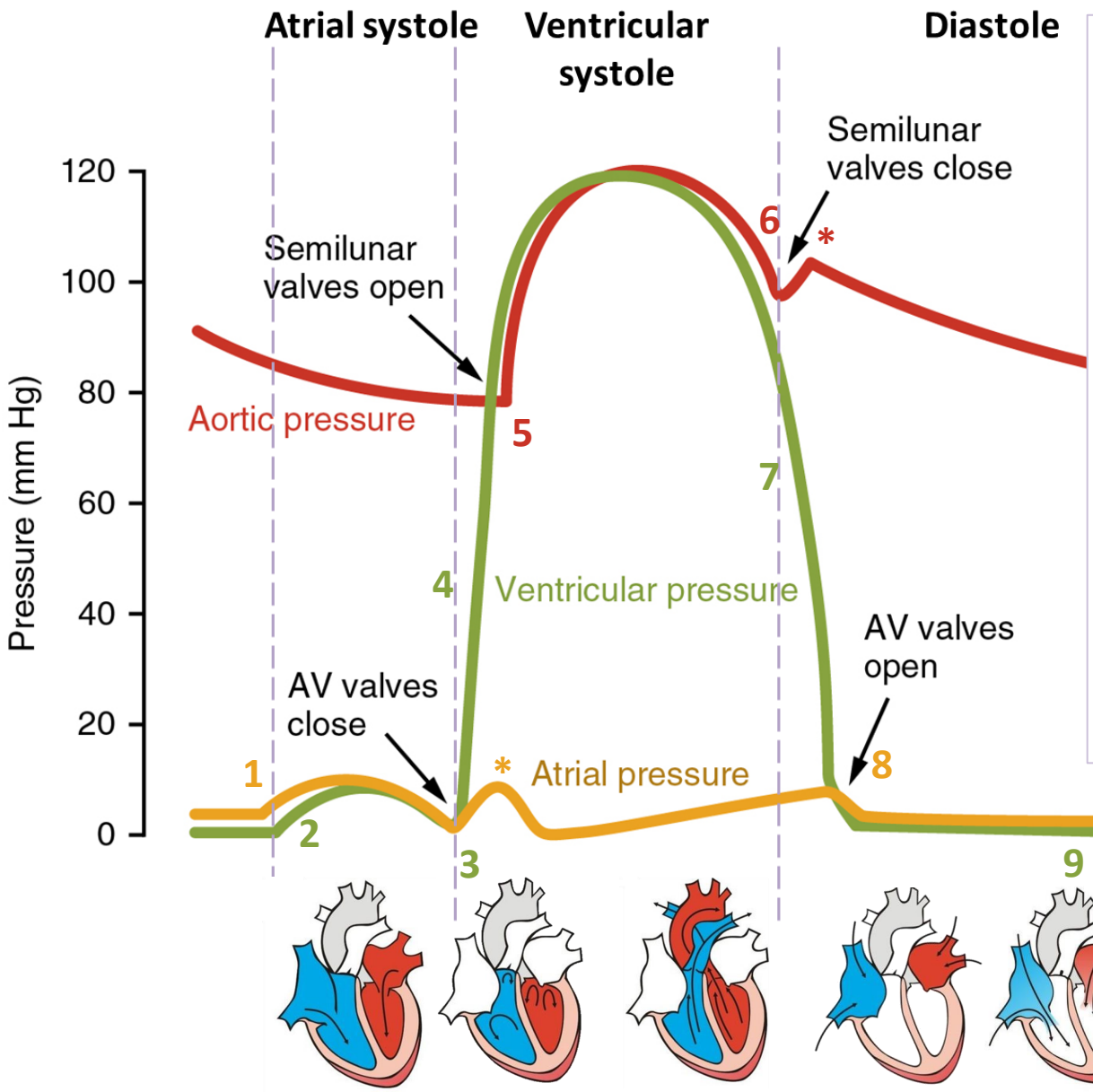
- Changes with stage of cardiac cycle
- Usually measure the pressure on the **left side of heart** → Left atrium, left ventricle, aorta
- Due to higher pressure and larger diff in pressure compared to right side

Generally:

- Atrial pressure is relatively low because it has thinner walls and exert less force
- **Atrial pressure** increases **during atrial systole**

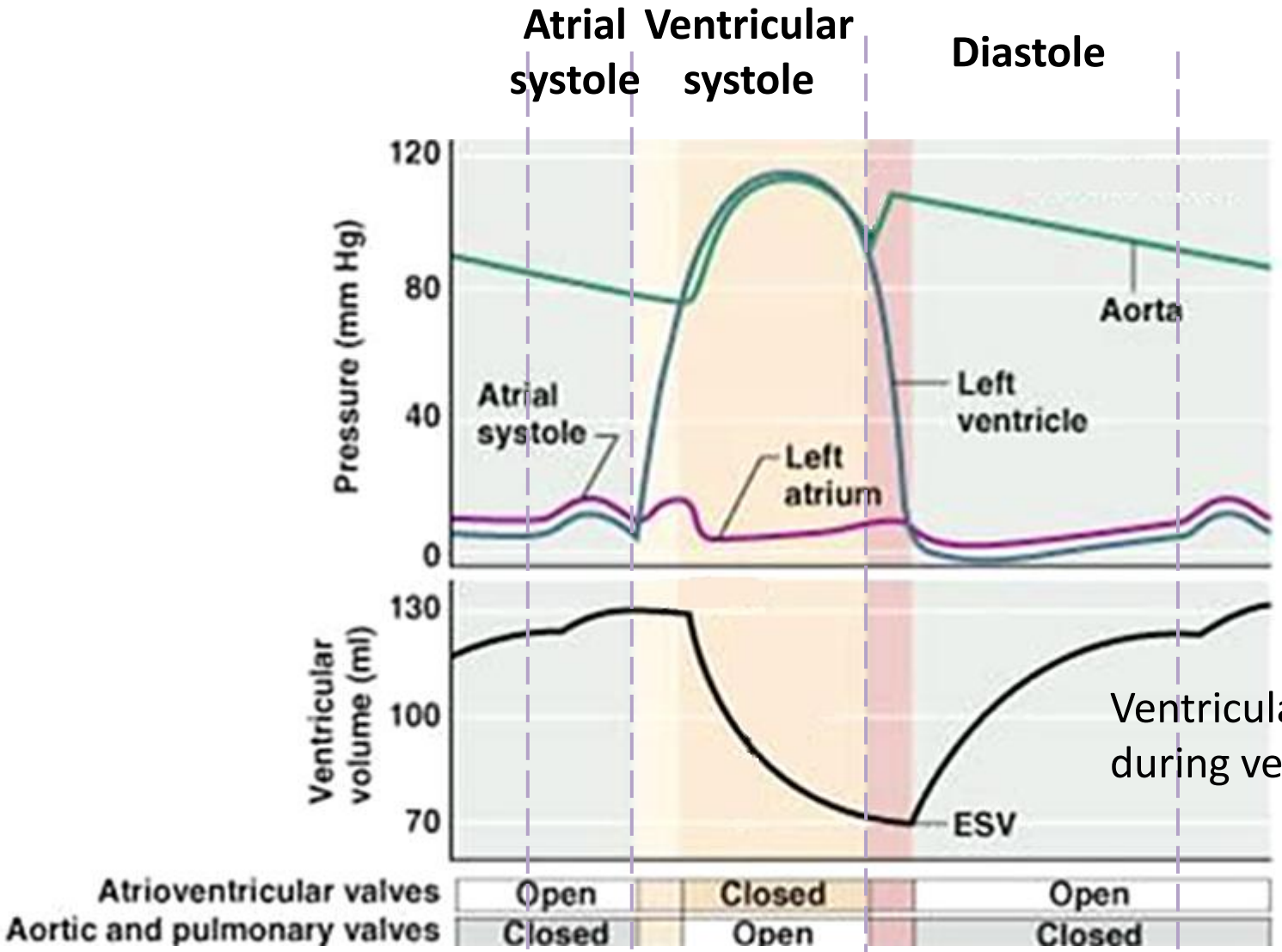
- **Ventricular pressure** increases during **ventricular systole**
- **Aortic pressure** increases during **ventricular systole**


Atrial systole
Ventricular systole
Diastole
Semilunar valves close
Semilunar valves open
120
100
80
60
40
20
0
Pressure (mm Hg)
Aortic pressure
Ventricular pressure
AV valves open
AV valves close
Atrial pressure
1st
2nd
Heart sounds
"Lub"
"Dub"



1 Atrial contraction begins
2 Blood enters ventricles
3 Ventricular systole begins; AV valves close
4 Ventricles contract
5 Semilunar valves open; Blood flows into arteries
6 Semilunar valve closes
7 Ventricles empty and relax
8 AV valves open; Blood starts to fill atria
9 Blood trickles into ventricle
** Pressure slightly increases when valves close

Changes in Ventricular Volume

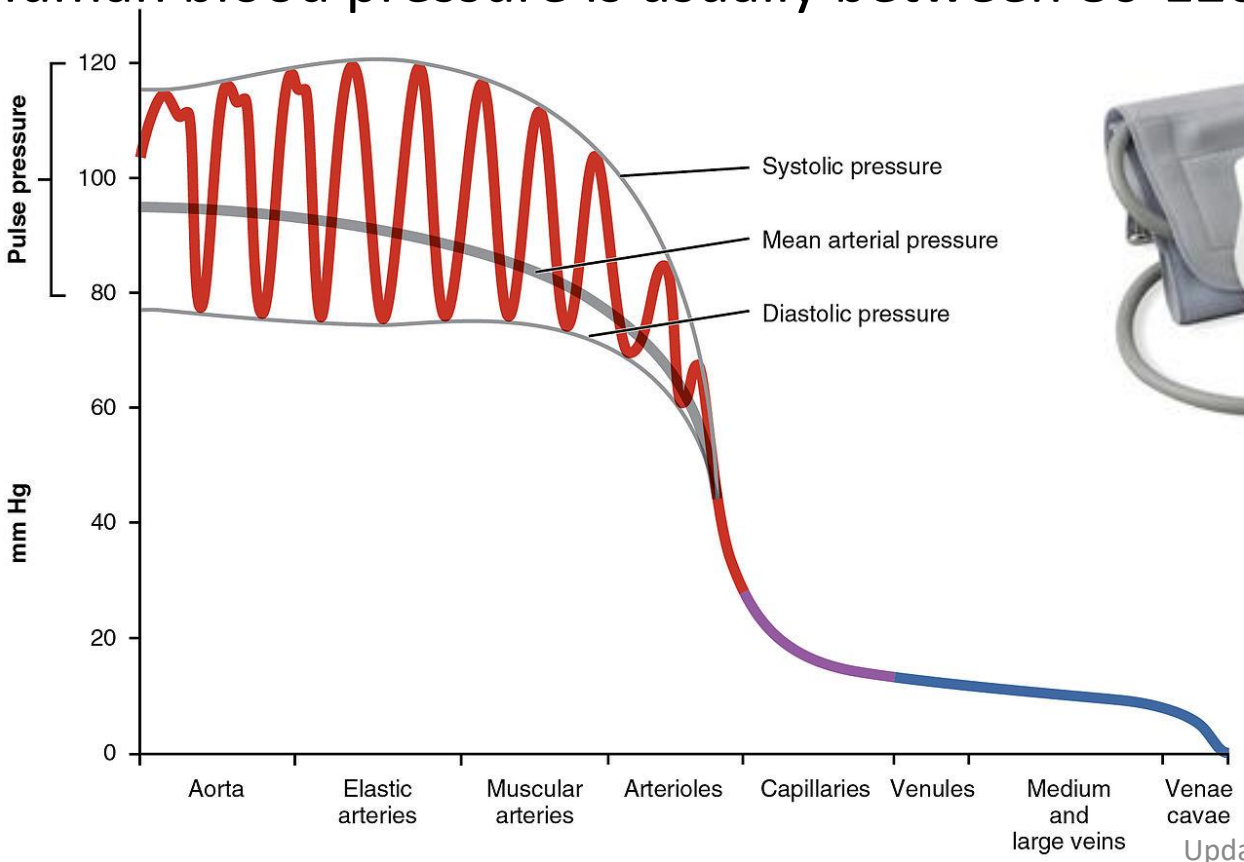


Ventricular volume drops during ventricular systole

Changes in Pressure in Blood Vessels

- Pulsates due to ventricular contraction
- **Systolic pressure** = the maximum blood pressure in the arteries
- **Diastolic pressure** = the minimum blood pressure in the arteries

- Human blood pressure is usually between 80-120mmHg

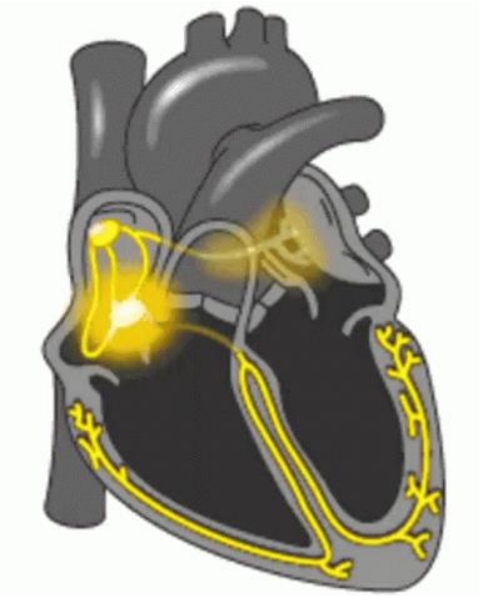


Control of Heart Beat

- Cardiac muscles are **myogenic**
- Myogenic = contraction initiated by muscles itself, not by nervous impulses from outside

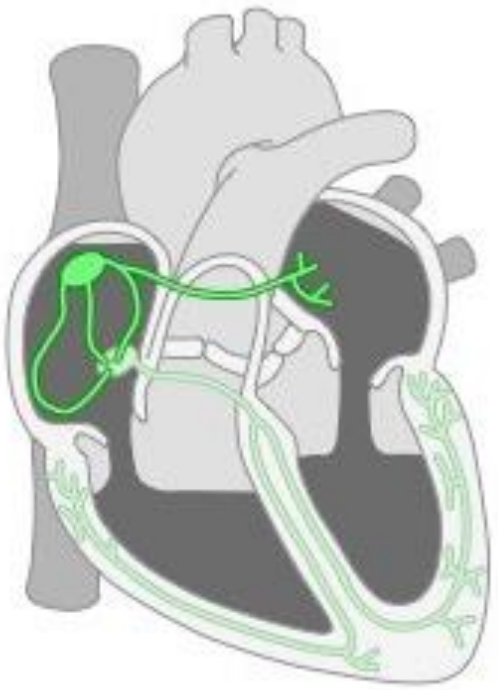
- How is the cardiac cycle initiated and coordinated?
- Wave of excitation/electrical impulse is passed through the:

1) **Sinoatrial node (SAN)**
2) **Atrioventricular node (AVN)**
3) **Purkyne tissue**



Sinoatrial node (SAN)

- Determines rhythm of heart
- Also called **pacemaker**
- Found at the wall of the right atrium



1. SAN / pacemaker sends out waves of excitation / **electrical impulses**

2. Impulses **spreads across atria**

→ Both atria contract simultaneously

→ Result in **atrial systole**

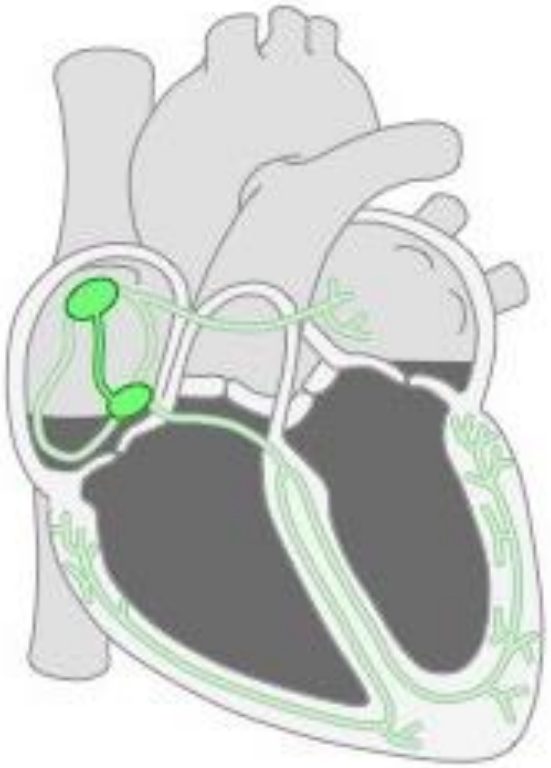
- But **non-conducting tissue** prevents impulses from reaching the ventricles

→ So atria and ventricles do not contract at the same time

- Wave of excitation passed to AVN

Atrioventricular node (AVN)

- AVN is found between the atria
- Prevents atria and ventricles from contracting at the same time
- Acts as a **relay station**



3. There is a **time delay** of ~0.1-0.2 seconds

→ Allows atria to empty

→ And ventricles to fill

4. AVN **sends wave of excitation to ventricles**

- Wave of excitation passed to Purkyne tissue

Purkyne tissue

- Tiny bundles of connecting fibres
- Found at base of ventricles

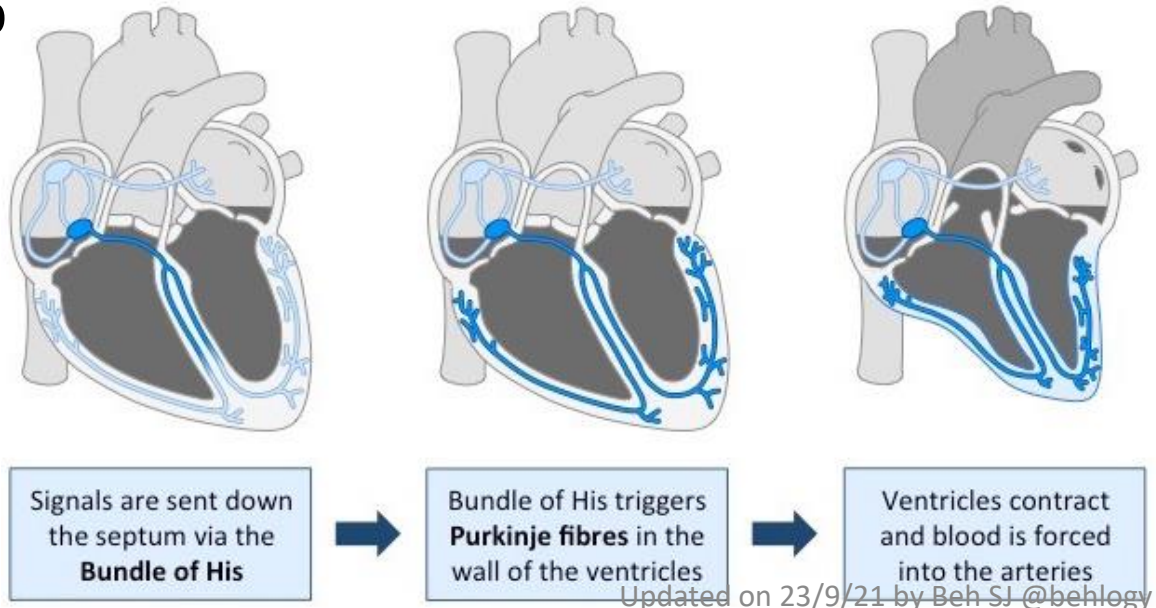
5. Purkyne tissue conducts excitation to **base of septum** / ventricles

6. **Electrical impulses spreads upwards** in ventricle walls

→ **Ventricle muscles contract from base upwards**

→ Ventricles force blood up from base

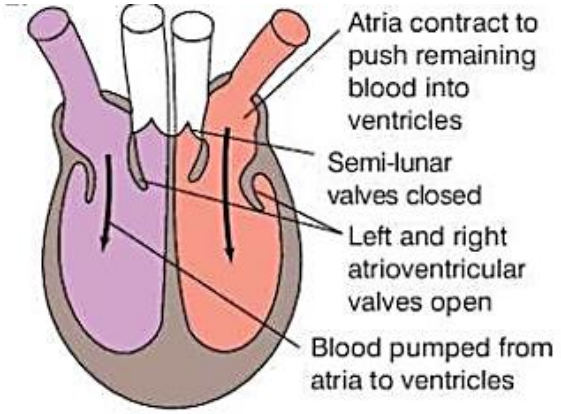
→ Result in **ventricular systole**


Signals are sent down the septum via the **Bundle of His**
Bundle of His triggers **Purkinje fibres** in the wall of the ventricles
Ventricles contract and blood is forced into the arteries

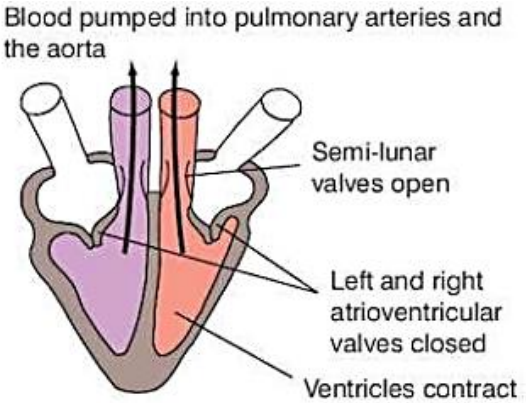
Updated on 23/9/21 by Beh SJ @behlogy

Refractory Period

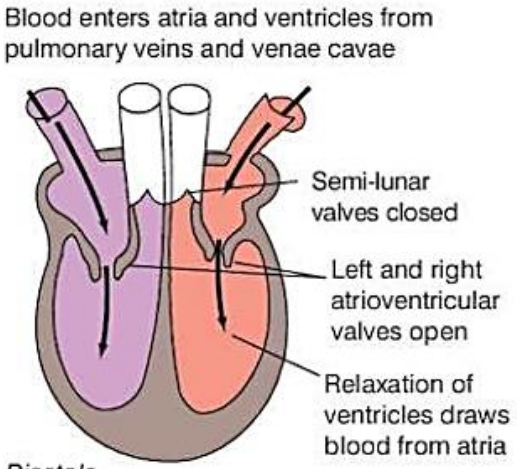
- **Period of insensitivity to any stimulation**
- ~0.4seconds
- Atrial and ventricular muscles relax
- **Diastole**


Atria contract to push remaining blood into ventricles
Semi-lunar valves closed
Left and right atrioventricular valves open
Blood pumped from atria to ventricles

Atrial systole
Atria contract, pushing blood into the ventricles. Ventricles remain relaxed.


Blood pumped into pulmonary arteries and the aorta
Semi-lunar valves open
Left and right atrioventricular valves closed
Ventricles contract

Ventricular systole
Atria relax. Ventricles contract, pushing blood away from heart through pulmonary arteries and the aorta.

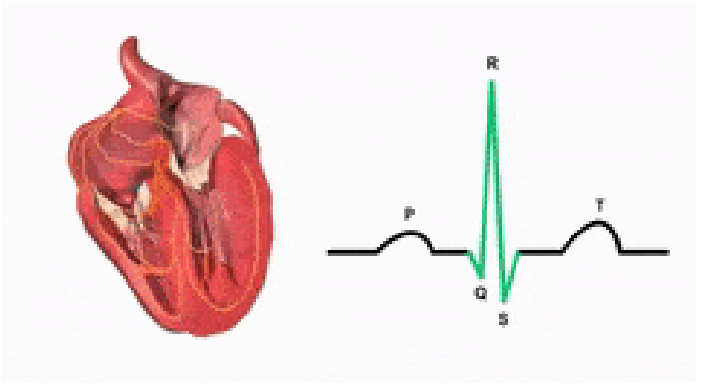

Blood enters atria and ventricles from pulmonary veins and venae cavae
Semi-lunar valves closed
Left and right atrioventricular valves open
Relaxation of ventricles draws blood from atria

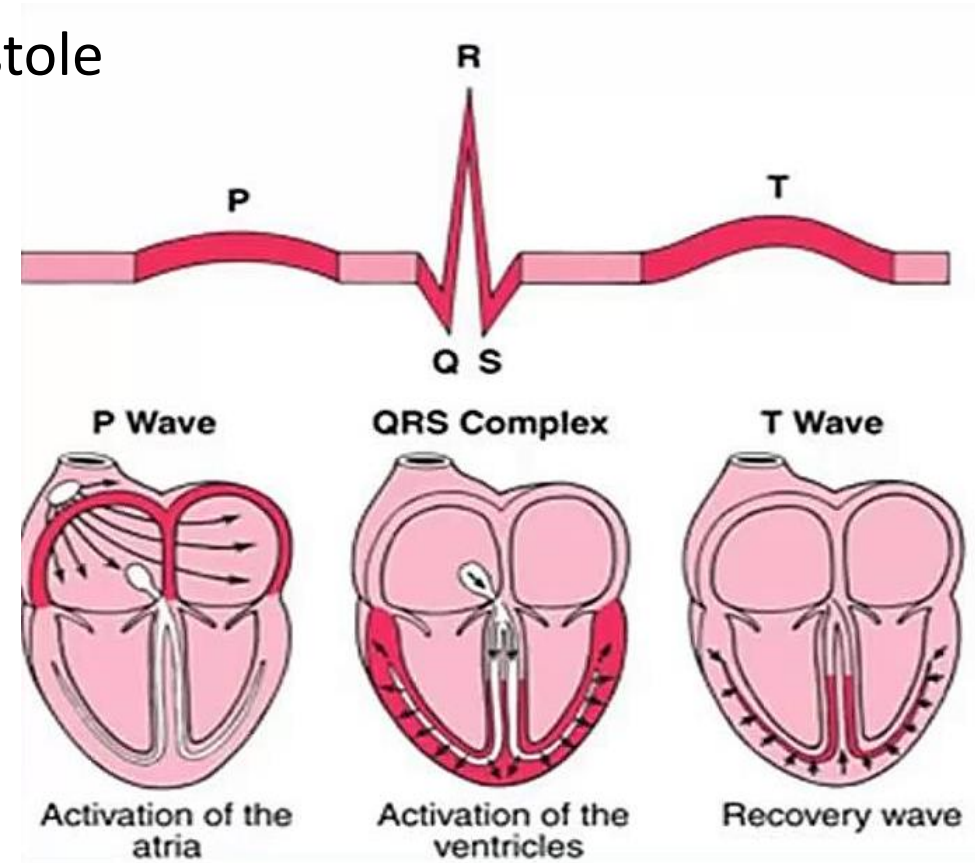
Diastole
Atria are relaxed and fill with blood. Ventricles are also relaxed.

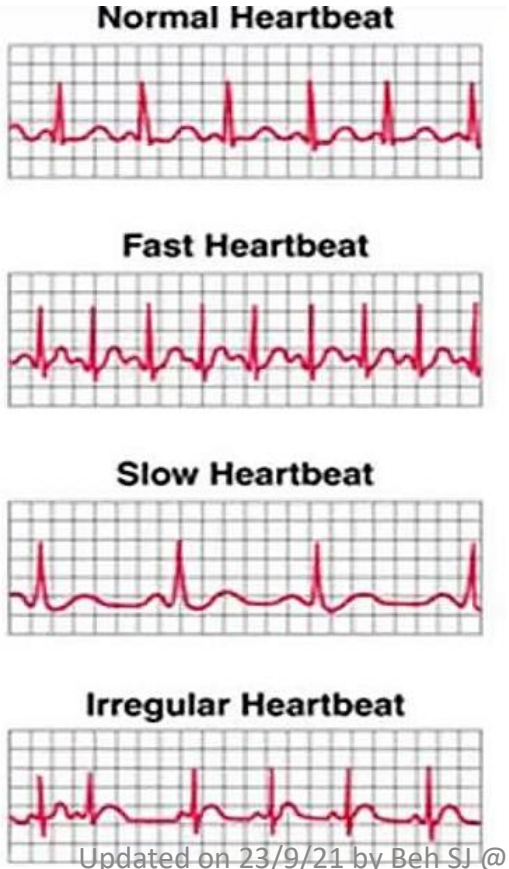
SAN → AVN → Purkyne tissue → Refractory Period

Electrocardiography (ECG)

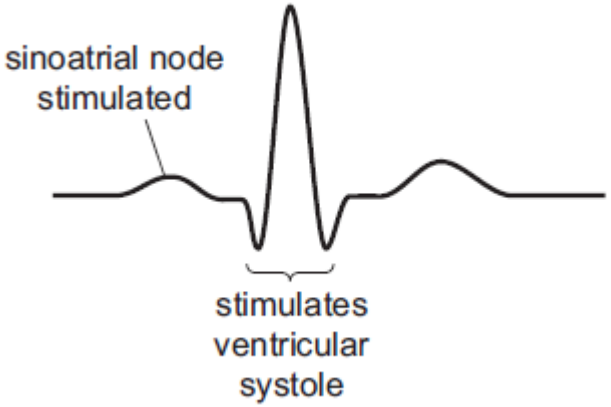
- Used to measure heart rate and regularity
- Records wave of electrical activity
- P = atrial systole
- QRS = ventricular systole
- T = diastole



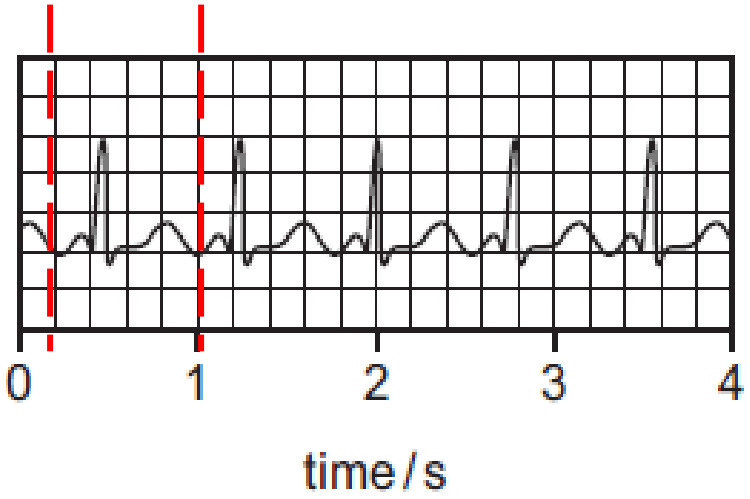




Calculating heart rate in bpm from an electrocardiogram



1 cardiac cycle = 0.8s



bpm = beats per minute

1. Find how long 1 cardiac cycle is

   1 cardiac cycle = 0.8 s

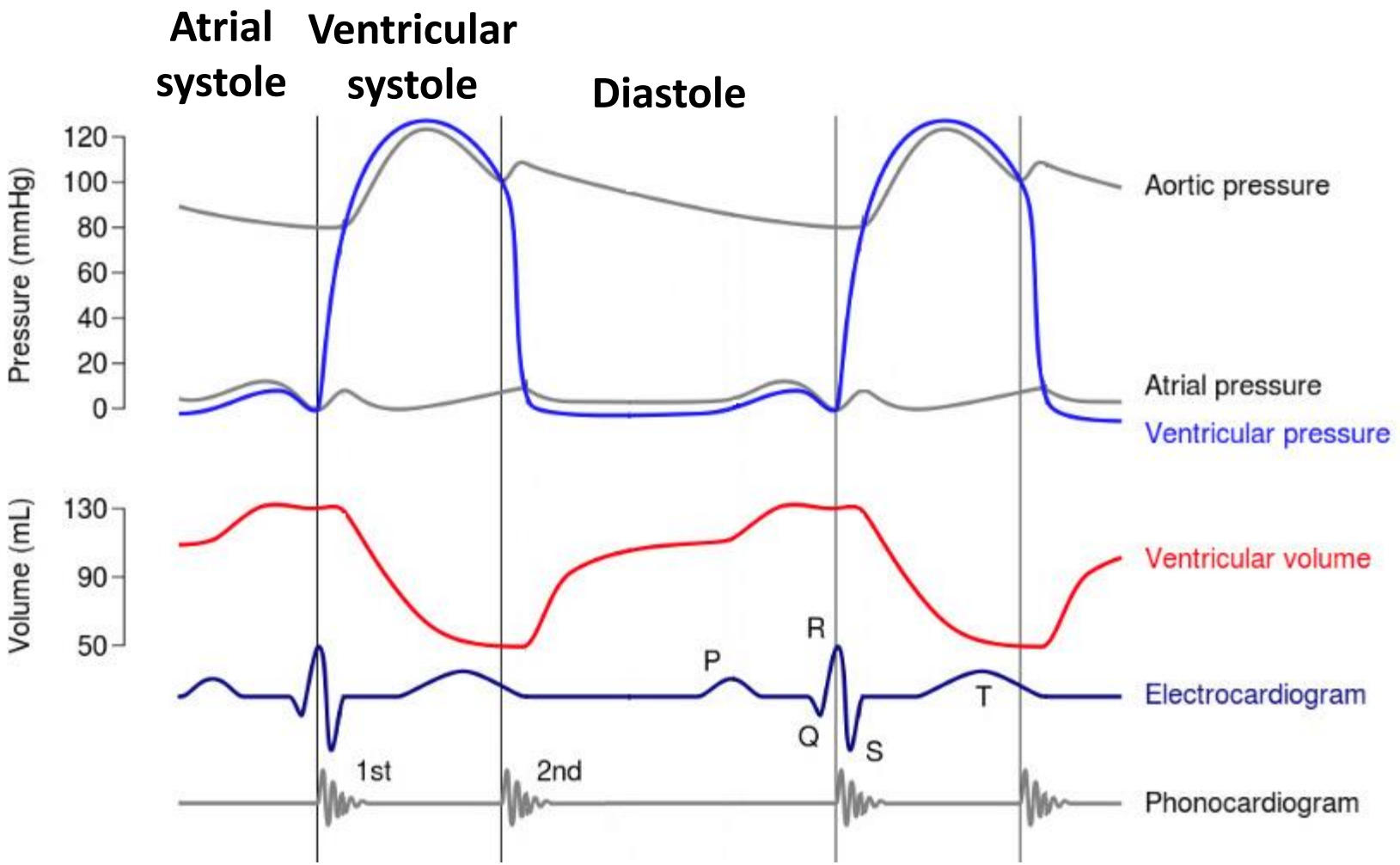
2. Find how many cardiac cycles occur per minute

   1 min ÷ 0.8 s

   = 60 s ÷ 0.8 s

   = 75bpm

Summary


Atrial systole
Ventricular systole
Diastole
Pressure (mmHg)
120
100
80
60
40
20
0
Aortic pressure
Atrial pressure
Ventricular pressure
Volume (mL)
130
90
50
Ventricular volume
R
P
T
Q
S
Electrocardiogram
1st
2nd
Phonocardiogram

Chapter Outline

Part 1: The Circulatory System

- Blood Vessels: Arteries, Veins and Capillaries
- Blood Plasma vs Tissue Fluid
- WBCs and RBCs

Part 2: Transport of oxygen and carbon dioxide

- The Haemoglobin Dissociation Curve
- Bohr effect and Transport of CO_2

Part 3: The Heart

- Structure of the Heart
- Cardiac Cycle
- Control of Heart Beat

Videos

- Haemoglobin Dissociation Curve + Bohr Effect

https://www.youtube.com/watch?v=vj8c2jiYI2g

- Respiratory System, part 2: Crash Course A&P #32

(How Blood Cells Exchange Oxygen and CO2 2:23
Partial Pressure Gradients 2:41
How Hemoglobin Binds to Gases in the Blood 4:40)

https://www.youtube.com/watch?v=Cqt4LjHnMEA